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VOLUME 29 JANUARY, 1955 NUMBER 1

FORAMINIFERA FROM THE PALEOCENE PALE GREDA FORMATION OF PERU

LAWRENCE WEISS

International Petroleum Company Limited, Talara, Peru

ABSTRACT—The foraminiferal assemblage from the Pale Greda formation of the International Petroleum Company's La Brea-Pariñas property in northwestern Peru consists of 74 species of smaller Foraminifera, including 12 new species and 2 new subspecies. The fauna is facies-controlled and represents deposition in both neritic and sublittoral environments. The majority of the species range in age from Upper Cretaceous to Eocene. A Paleocene age is indicated by the faunal similarity with the Midway formation of the Gulf Coast region and by the presence of several species of *Globorotalia* which are limited to the Paleocene in Cuba and Trinidad. New species described are: *Schenckiella stainforthi, Robulus youngquisti, Astacolus peruvianus, Frondicularia palegredensis, Bulimina crenata, B. virguliniformis, B. fissura, Virgulina dorreeni, Valvulineria palegredensis, Chilostomella polsoni, Globigerina stonei, Globorotalia whitei.* New subspecies described are *Marginulina adunca* (Franzenau) *aquilina* and *Gyroidina depressa* (Alth) *parvula.*

INTRODUCTION

THE La Brea-Pariñas property of the International Petroleum Company Ltd., lies in the highly faulted taphrogenic province of northwestern Peru. The area is a thin strip of coastal desert between the Amotape Mountains to the east and the Pacific Ocean to the west. Stratigraphically, the section consists of a basement complex of Paleozoic argillite, intruded by granite and overlain by a thick series of Cretaceous and Tertiary sediments with a thin veneer of Pleistocene marine deposits (see Fig. 1).

The Tertiary is represented by some 20,000 feet of Paleocene-Eocene marine clastic sediments. This thickness, however, is highly variable due to deposition in local basins and to middle-upper Eocene angular unconformities. Foraminifera have been described from four of these formations by Frizzell (1943) and Cushman and Stone (1947, 1949). In the present paper, as a continuation of the effort to complete the systematic study of the Foraminifera of northwestern Peru, the Foraminifera of the Pale Greda formation are described and figured.

The Pale Greda formation was first referred to as the "Pale Shales" member of the Clavilithes series by Bosworth (1922, pp. 23, 28). The term "Palida Greda" was subsequently used by company geologists and later emended to "Pale Greda" by Iddings and Olsson (1928, p. 13). Wiedey and Frizzell (1939) change the name to "Keswick shale," but the change was not adopted in company usage and the name Pale Greda continues to be applied to the formation.

Although the early authors did not desig-

nate a type locality, Iddings and Olsson delineated the area of maximum exposure, and Frizzell, in a company report, considered this area (Square Mile 2-N-3 and 2-N-4) to represent the type locality of the formation.

LITHOLOGY AND FACIES DISTRIBUTION

In the type locality, the Pale Greda formation is 2200 feet thick, consisting of grey clay shale, silty shale, and lenses of very fine, grey, silty sandstone, conformable with the subjacent Salina formation and the suprajacent Pariñas formation. The Pale Greda-Pariñas contact is marked by a rather abrupt change from silty shale to the massive Pariñas sandstone. The Pale Greda-Salina contact is less apparent, with the Salina marked by an increase in sandstone interbedded with dark, micaceous shale. The area is one of cyclic deposition and repeated facies, with the Pale Greda formation representing deposition during a period of marine transgression between the partial regressive phases of the Pariñas and Salina seas.

Three facies types, based on faunal and lithologic evidence, are recognized in the Pale Greda formation. An orderly lateral transition can be discerned from an offshore neritic deposit containing abundant Foraminifera, to a shallow-water sublittoral zone with sparse Foraminifera, micromolluscs, ostracods, and echinoids, and finally to the littoral facies consisting of sandstones and occasional conglomerates.

AGE AND CORRELATION

Of the Pale Greda benthonic Foraminifera recorded in the literature, 70 percent of the species are restricted to an Upper Cretaceous-Eocene range. However, many of these late Cretaceous formations are now considered to be Paleocene in age, e.g., the Velasco and Tabasco shales of Mexico, and the Lizard Springs formation of Trinidad. Most of the previous literature on the La Brea-Pariñas area placed the Pale Greda formation in the lower Eocene. However, the term lower Eocene was used loosely to include all of the oldest Tertiary sediments. Travis (1953, p. 2100) points out the probability of a Paleocene age for the Pale Greda, Salina-Negritos and Balcones formations and in the opinion of the writer that is actually the case.

Eleven benthonic and one pelagic Pale Greda species have been reported from the Paleocene Midway formation of the Gulf Coast region, viz.

Ammobaculites midwayensis
Ammobaculites expansus
Spiroplectammina rossae
Dentalina eocenica
Nodosaria affinis
Pseudoglandulina manifesta
Cibicides newmanae
Bulimina arkadelphiana var. *midwayensis*
Siphogenerina eleganta
Epistomina eocenica
Globigerina triloculinoides
Anomalina welleri

Thus, the Pale Greda benthonic species indicate a Paleocene-Eocene age, but some of the planktonic Foraminifera offer con-

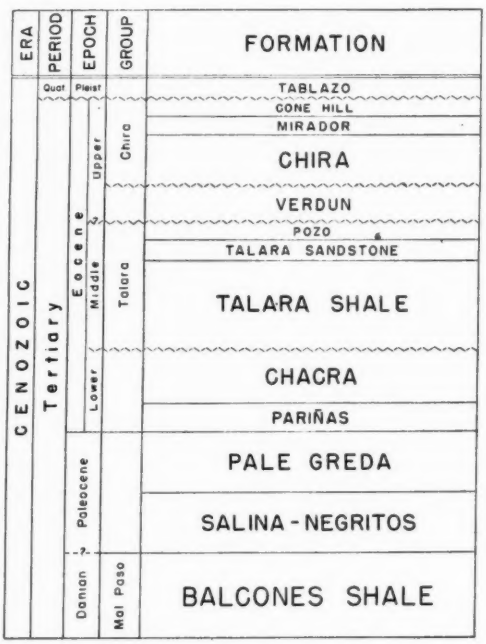

FIG. 1—Tertiary columnar section for the La Brea-Pariñas property.

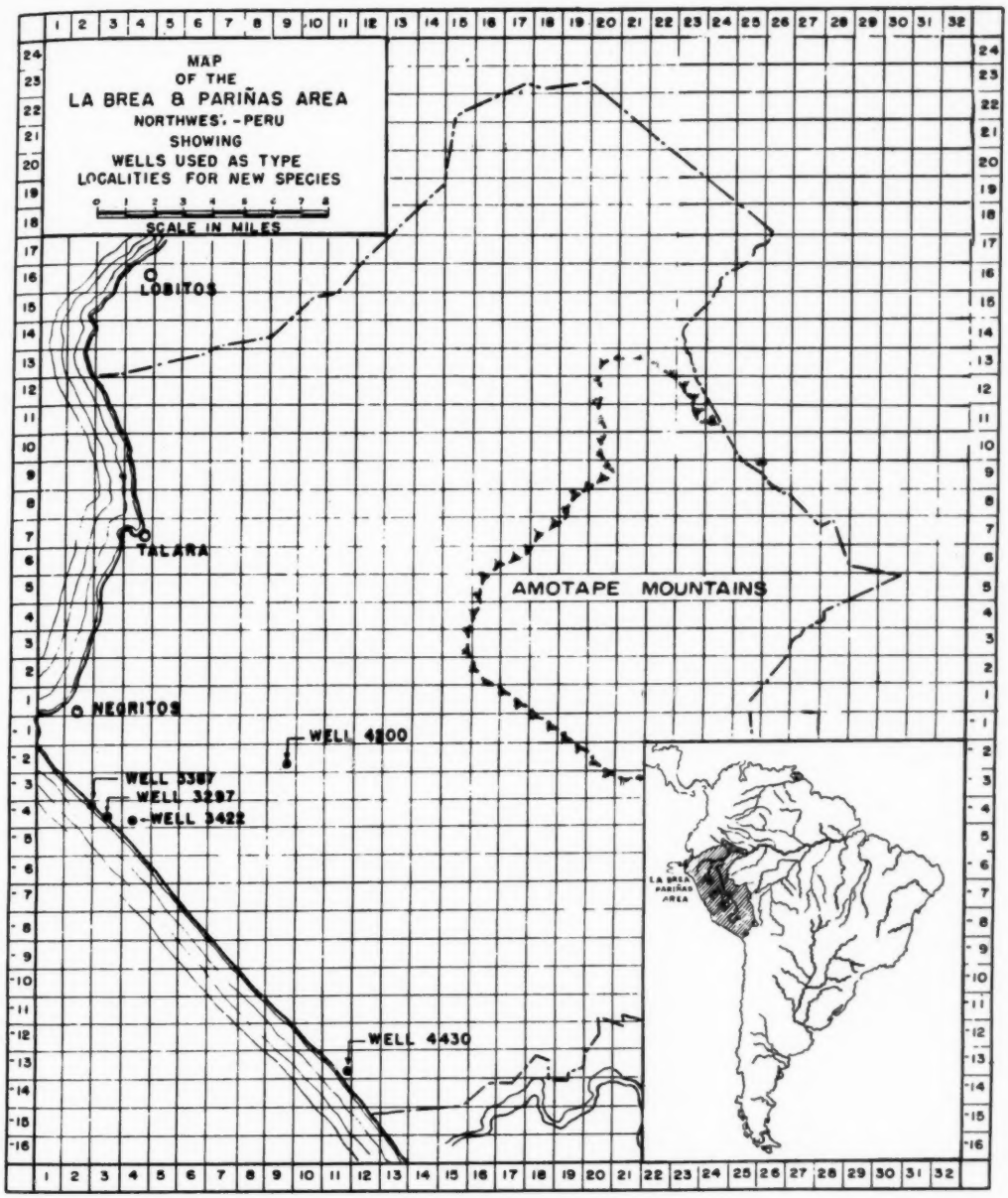
MAP
OF THE
LA BREA & PARIÑAS AREA
NORTHWEST - PERU
SHOWING
WELLS USED AS TYPE
LOCALITIES FOR NEW SPECIES
SCALE IN MILES
LOBITOS
TALARA
NEGRITOS
AMOTAPE MOUNTAINS
WELL 4200
WELL 5387
WELL 3297
WELL 3422
WELL 4430
LA BREA PARIÑAS AREA

FIG. 2

vincing evidence for limiting the Pale Greda formation to Paleocene time.

The most common planktonic genera represented in the Pale Greda are *Globigerina* and *Globorotalia*. The genus *Globigerina* did not undergo an appreciably marked evolutionary trend in the earliest Tertiary and therefore, for that period of geologic time, *Globigerina* species are questionable as regional index fossils. Such is the case with the globigerinas of the Peruvian Eocene. Various species of the genus range throughout the stratigraphic column and are of limited value as zonal markers. On the other hand, as a result of the rapid evolution of *Globorotalia* during Paleocene-Eocene time, several species of that genus are highly reliable as index fossils on a regional scale. Two *Globorotalia* species of the Pale Greda formation, *G. crassata* var. *aequa* and *G. wilcoxensis*, are Paleocene markers in Cuba (Cushman and Bermudez, 1949, pp. 37, 39), and *G. crassata* var. *aequa* is an important Paleocene index fossil in Trinidad (Bolli, 1952). In the La Brea-Pariñas area, these species are present in the Negritos shale zonule of the Salina formation and range only to the top of the Pale Greda, strongly indicating a Paleocene age for both formations.

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The writer also wishes to express his thanks to Dr. Katherine V. W. Palmer of the Paleontological Research Institution at Ithaca, New York, and to Miss Ruth Todd of the U. S. National Museum, Wash-

EXPLANATION OF PLATE 1

FIGS. *1*—*Astrorhiza* cf. *A. arenaria* Carpenter, ×20. I.P.Co. well 3422, core depth 3162–3190′. (p. 5)

2—*Bathysiphon eocenicus* Cushman & G. D. Hanna, ×20. I.P.Co. well 3387, core depth 1507–1542′. (p. 5)

3–5—*Alveolophragmium peruvianum* Maync, ×40. *3*, *4*, reflected light; *5*, transmitted light. I.P.Co. well 3387, core depth 1507–1542′. (p. 6)

6, *7*—*Haplophragmoides carinatus* Cushman & Renz, ×40. I.P.Co. well 3422, core depth 3162–3190′. (p. 5)

8, *9*—*Haplophragmoides* sp., ×40, I.P.Co. well 3387, core depth 1507–1542′. (p. 6)

10, *11*—*Ammobaculites midwayensis* Plummer, ×40. *10*, reflected light; *11*, transmitted light. I.P.Co. well 3580, core depth 3843–3862′. (p. 6)

12, *13*—*Ammobaculites expansus* Plummer, ×60. *12*, reflected light; *13*, transmitted light. I.P.Co. well 3621, core depth 2739–2742′. (p. 6)

14, *15*—*Trochammina* cf. *T. asagaiensis* Asano, ×60. I.P.Co. well 3695, core depth 2675–2693′. (p. 8)

16, *17*—*Trochammina depressa* Lozo, ×60. I.P.Co. well 3422, core depth 3162–3190′. (p. 8)

18, *19*—*Trochammina globigeriniformis* (Parker & Jones), ×60. I.P.Co. well 3387, core depth 1507–1542′. (p. 8)

20, *21*—*Spiroloculina cretacea* Reuss, ×60. I.P.Co. well 3422, core depth 3241–3248′. (p. 8)

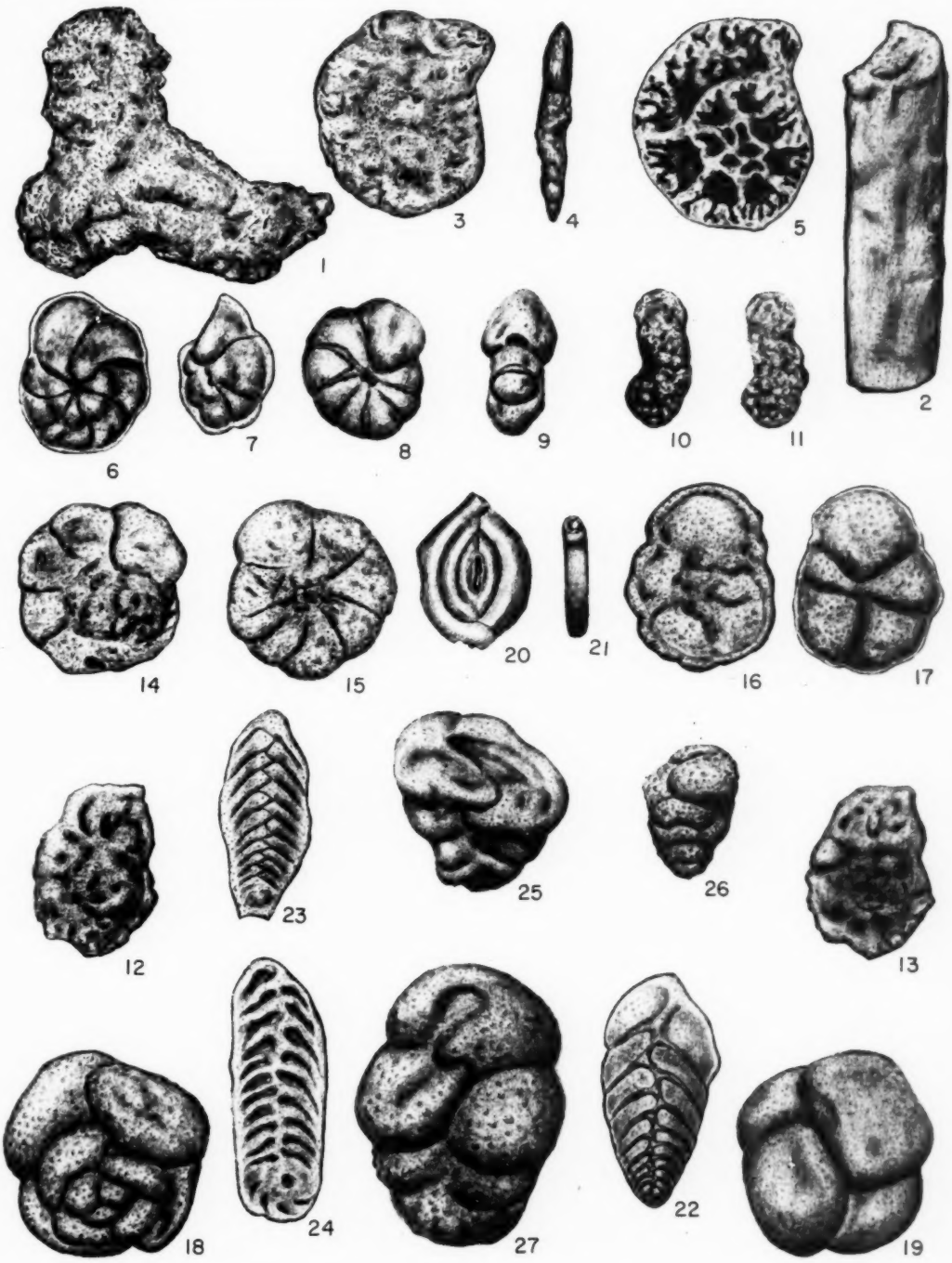
22—*Spiroplectammina rossae* Plummer, ×60. I.P.Co. well 3422, core depth 3241–3248′. (p. 7)

23, *24*—*Spiroplectammina grzybowskii* Frizzell, ×60. *23*, reflected light; *24*, transmitted light. I.P.Co. well 3422, core depth 3162–3190′. (p. 7)

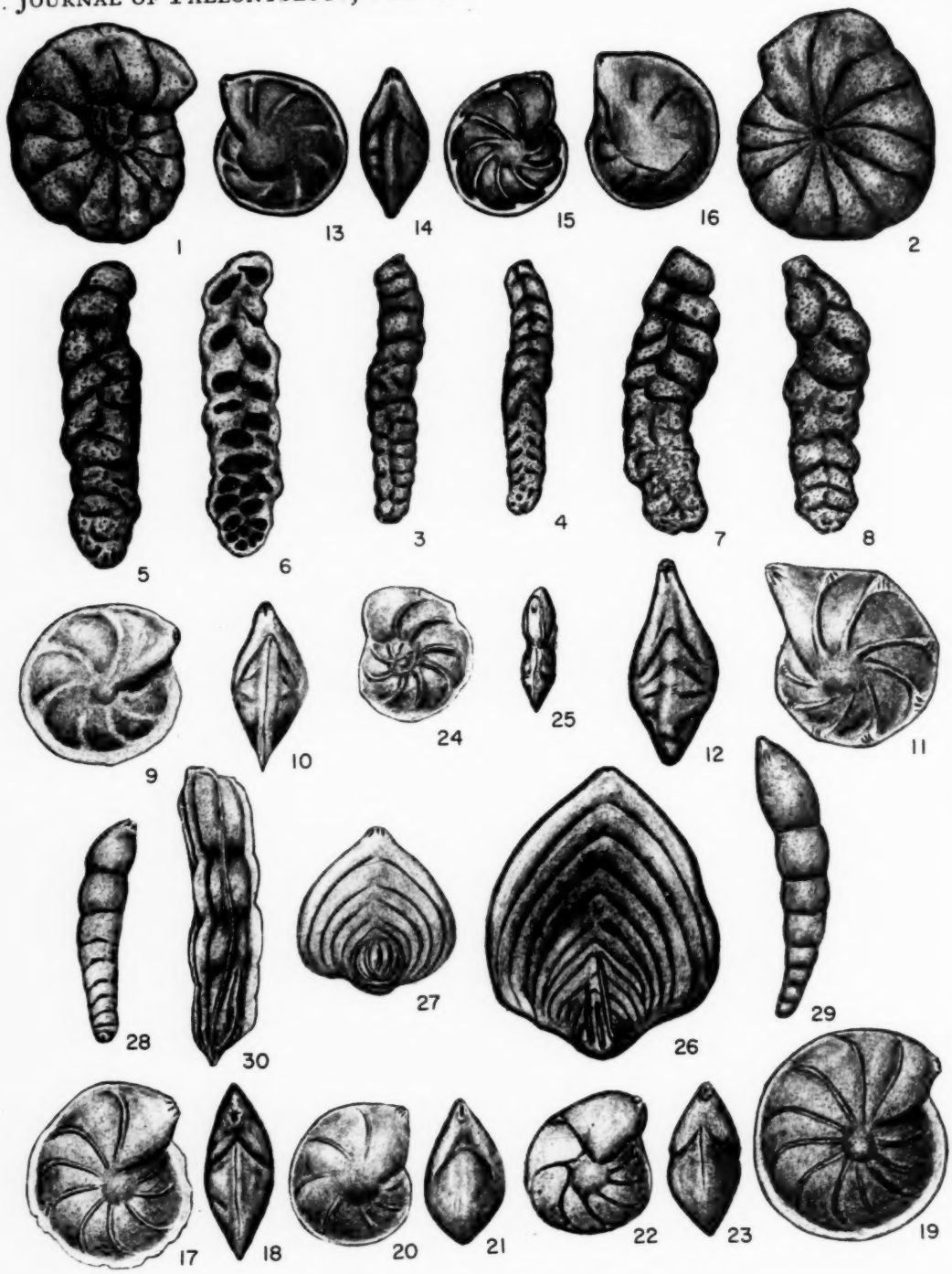
25—*Textularia* cf. *T. orbica* Lalicker & McCulloch, ×60. I.P.Co. well 3422, core depth 3162–3190′. (p. 7)

26—*Textularia* sp., ×60. I.P.Co. well 3422, core depth 3162–3190′. (p. 7)

27—*Verneuilina* cf. *V. polystropha* (Reuss), ×60. I.P.Co. well 3422, core depth 3162–3190′. (p. 7)



Weiss, Paleocene Foraminifera, Peru



Weiss, Paleocene Foraminifera, Peru

ington, D. C., for the use of their laboratories and facilities to check type material wherever possible.

The holotypes, figured specimens, and unsorted type material have been deposited in the Department of Micropaleontology, American Museum of Natural History, New York, New York.

SYSTEMATIC DESCRIPTIONS

Family ASTRORHIZIDAE
Genus ASTRORHIZA Sandahl, 1858
ASTRORHIZA cf. A. ARENARIA Carpenter
Plate 1, figure 1

?Astrorhiza sp. CARPENTER, 1876, Quart. Jour. Micr. Sci., p. 221, pl. 19, figs. 1–13.
?Astrorhiza arenaria CARPENTER in Norman, 1876, Royal Soc. London, Proc., vol. 25, p. 213.

A few specimens in the Pale Greda formation compare well with the Recent forms.

Family RHIZAMMINIDAE
Genus BATHYSIPHON M. Sars, 1872
BATHYSIPHON EOCENICUS Cushman & G. D. Hanna
Plate 1, figure 2

(For references and figures see Cushman, 1951, U. S. Geol. Survey Prof. Paper 232, p. 3, pl. 1, figs. 1, 2.)

The surface coloration of the Pale Greda specimens varies from brown to black.

Nauss (1947, p. 334, pl. 48, fig. 4) erected *B. vitta* as distinct from *B. eocenicus* on the basis of color, wall thickness, and compression. However, *B. vitta* falls within the range of variation of the Pale Greda *B. eocenicus* and very probably should be referred to the latter species.

B. eocenicus is rare to common in the Pale Greda formation and is also present in some of the Eocene formations in northwestern Peru.

Family LITUOLIDAE
Genus HAPLOPHRAGMOIDES Cushman, 1910
HAPLOPHRAGMOIDES CARINATUS Cushman & Renz
Plate 1, figures 6, 7

Haplophragmoides carinatum CUSHMAN & RENZ, 1941, Cushman Lab. Foram. Research Contr., vol. 17, p. 2, pl. 1, fig. 1.

This species is rare to common in the Pale Greda formation. Specimens average six to eight chambers in the adult whorl as compared with the eight- to ten-chambered type material, and are often longitudinally compressed, as shown in figure 7.

H. carinatus also occurs in the Eocene

EXPLANATION OF PLATE 2

FIGS. *1, 2—Cyclammina* cf. *C. simiensis* Cushman & McMasters, ×20. Two specimens, I.P.Co. well 3387, core depth 1507–1542′. (p. 7)
3, 4—Schenckiella stainforthi Weiss, n. sp., ×40. Holotype. *3*, reflected light; *4*, transmitted light. I.P.Co. well 3422, core depth 3162–3190′. (p. 8)
5–8—Schenckiella stainforthi Weiss, n. sp., ×60. *5*, *7*, *8*, reflected light; *6*, transmitted light. I.P.Co. well 3387, core depth 1507–1542′. (p. 8)
9, 10—Robulus pseudocultratus Cole, ×40. I.P.Co. well 3422, core depth 3162–3190′. (p. 9)
11, 12—Robulus alabamensis Cushman, ×40. I.P.Co. well 3422, core depth 3162–3190′. (p. 9)
13–16—Robulus youngquisti Weiss, n. sp., ×40. *13–15*, holotype, *15* by transmitted light; *16*, paratype. I.P.Co. well 3387, core depth 1507–1542′. (p. 9)
17–19—Robulus cf. *R. navarroensis* (Plummer), ×40. *17*, *18*, keeled specimen, I.P.Co. well 3387, core depth 1507–1542′; *19*, specimen with worn keel, I.P.Co. well 3422, core depth 3162–3190′. (p. 9)
20, 21—Robulus sp. A, ×60. I.P.Co. well 4430, core depth 5074–5083′. (p. 9)
22, 23—Robulus sp. B, ×60, I.P.Co. well 4430, core depth 5074–5083′. (p. 9)
24, 25—Astacolus peruvianus Weiss, n. sp., ×40. Holotype. I.P.Co. well 3422, core depth 3241–3248′. (p. 10)
26, 27—Frondicularia palegredensis Weiss, n. sp., ×20. *26*, holotype. *27*, young paratype. I.P.Co. well 3422, core depth 3162–3190′. (p. 11)
28—Dentalina colei Cushman & Dusenbury, ×40. I.P.Co. well 3422, core depth 3162–3190′. (p. 10)
29—Dentalina eocenica Cushman, ×60. I.P.Co. well 3422, core depth 3241–3248′. (p. 11)
30—Dentalina alternata (Jones), ×40. I.P.Co. well 3422, core depth 3241–3248′. (p. 11)

sediments in the La Brea-Pariñas area and therefore, although the Pale Greda form differs slightly in color and texture, it is not a reliable horizon marker.

HAPLOPHRAGMOIDES sp.
Plate 1, figures 8, 9

Test small, slightly longer than broad, biumbilicate, periphery rounded and lobulate; an average of eight chambers in the adult whorl (ten in the figured specimen), slightly inflated; sutures limbate, depressed; wall finely arenaceous with siliceous cement; aperture an arched slit at the base of the last septal face, usually not discernible.

Dimensions of figured specimen: greatest diameter 0.60 mm.; thickness of last chamber 0.20 mm.

Figures 8 and 9 are of one of the very rare non-distorted forms of this species. The specimens are often smaller and usually badly crushed and deformed with a variable axis of distortion. More well-preserved specimens are necessary before a specific name can be assigned.

Genus ALVEOLOPHRAGMIUM
Stschedrina, 1936
ALVEOLOPHRAGMIUM PERUVIANUM Maync
Plate 1, figures 3–5

Ammobaculites cf. *A. foliaceus* (Brady), CUSHMAN & STONE, 1949, Cushman Lab. Foram. Research Contr., vol. 25, p. 76, pl. 13, figs. 14a–b.

Alveolophragmium peruvianum MAYNC, 1952, Cushman Found. Foram. Research Contr., vol. 3, p. 142, pl. 26, figs. 11, 12.

Many of the Pale Greda specimens are identical to that figured by Cushman and Stone in that no chamber arrangement is detectable. However, with transmitted light, some of the pyritized Pale Greda forms readily exhibit the chamber arrangement of the species.

Although the reticulate surface pattern is not observable on this species, the labyrinthic or alveolar structure of the test seems to validate Maync's generic designation. The Pale Greda species may be described as follows:

Test small, very highly compressed, composed of two to two and one-half whorls, circular or slightly longer than broad, periphery slightly lobulate; chambers six to eight in the adult whorl, labyrinthic; sutures indistinct, or visible only as non-pyritized partitions between the pyrite-filled chambers; wall roughly arenaceous with siliceous cement; aperture not discernible.

Dimensions of figured specimen: length 0.75 mm.; breadth 0.65 mm.; thickness 0.05 mm.

A. peruvianum is a fairly common Pale Greda species but of questionable value as an index fossil as it occurs rarely in the stratigraphically younger Verdun formation on the La Brea-Pariñas property.

Genus AMMOBACULITES
Cushman, 1910

The two species which represent this genus in the Pale Greda formation are characteristic of the Paleocene uppermost Midway formation of Texas. In the La Brea-Pariñas area, these *Ammobaculites* species are found only in the silty shale, sublittoral, sparsely fossiliferous facies of the Pale Greda formation. Both Midway holotypes examined by the writer are more coarsely arenaceous than the Pale Greda specimens —a factor very likely influenced by ecologic conditions.

AMMOBACULITES MIDWAYENSIS Plummer
Plate 1, figures 10, 11

Ammobaculites midwayensis PLUMMER, 1933, Texas Univ. Bull. 3201, p. 63, pl. 5, figs. 7–11.

A very rare form in the Pale Greda material, with a single whorl and a comparatively long uniserial stage.

AMMOBACULITES EXPANSUS Plummer
Plate 1, figures 12, 13

Ammobaculites expansus PLUMMER, 1933, Texas Univ. Bull. 3201, p. 65, pl. 5, figs. 4–6.

Although smaller, the Pale Greda specimens agree very well with the Midway forms. *A. expansus* is fairly common and an excellent horizon marker in a few wells which are otherwise sparsely fossiliferous.

Genus CYCLAMMINA H. B. Brady, 1876
CYCLAMMINA cf. C. SIMIENSIS Cushman & McMasters
Plate 2, figures 1, 2

?Cyclammina simiensis CUSHMAN & MCMASTERS, 1936, Jour. Paleontology, vol. 10, no. 6, p. 509, pl. 74, figs. 3a, b.

The smooth-surfaced Pale Greda specimens have 12 to 13 chambers in the adult whorl, are often compressed laterally, and some specimens show a tendency toward becoming evolute in the final whorl.

A fairly common but variable form which may easily be confused with similar *Cyclammina* species in the younger formations in northwestern Peru.

Family TEXTULARIIDAE
Genus SPIROPLECTAMMINA Cushman, 1927
SPIROPLECTAMMINA ROSSAE Plummer
Plate 1, figure 22

Spiroplectammina rossae PLUMMER, 1933, Texas Univ. Bull. 3201, p. 66, pl. 5, figs. 1–3.

The Pale Greda and Midway forms of this strongly compressed species seem to be identical. *S. rossae* is rare to common and a good Pale Greda index fossil.

SPIROPLECTAMMINA GRZYBOWSKII Frizzell
Plate 1, figures 23, 24

Spiroplectammina grzybowskii FRIZZELL, 1943, Jour. Paleontology, vol. 17, p. 339, pl. 55, figs. 12–13;——CUSHMAN & RENZ, 1946, Cushman Lab. Foram. Research Special Pub. 18, p. 20, pl. 5, figs. 34–38.

Typical forms of this species are common in the Pale Greda material. It also occurs in formations both stratigraphically higher and lower on the La Brea-Pariñas property.

Genus TEXTULARIA Defrance, 1824
TEXTULARIA cf. T. ORBICA Lalicker & McCulloch
Plate 1, figure 25

?Textularia orbica LALICKER & MCCULLOCH, 1940, Univ. Southern Calif., Publ., Allan Hancock Pacific Exped., vol. 6, no. 2, p. 136, pl. 15, fig. 17.

A single specimen which may be compared with *T. orbica* was found in the Pale Greda. It is also somewhat similar to *T. subconica* Franke from the Taylor marl, Lamar County, Texas (Cushman, 1946, p. 30, pl. 6, figs. 21, 22).

TEXTULARIA sp.
Plate 1, figure 26

This is another single specimen from the Pale Greda material. It is a very small (probably immature), roughly arenaceous form with few chambers. The aperture is indistinct but appears to be situated in an elongated depression on the apex of the last chamber parallel to the short axis of the test. No similar species was observed in the literature. Dimensions: length 0.30 mm.; greatest width 0.20 mm.

Family VERNEUILINIDAE
Genus VERNEUILINA d'Orbigny, 1840
VERNEUILINA cf. V. POLYSTROPHA (Reuss)
Plate 1, figure 27

?Bulimina polystropha REUSS, 1846, Verstein. Böhm. Kreidef., pt. 2, p. 109, pl. 24, fig. 53. *Verneuilina polystropha* (Reuss), CUSHMAN & JARVIS, 1932, U. S. Nat. Mus. Proc., vol. 80, art. 14, p. 15, pl. 4, figs. 3a, b;——CUSHMAN & RENZ, 1946, Cushman Lab. Foram. Research Special Pub. no. 18, p. 20, pl. 2, fig. 16.

Although the Pale Greda forms are usually found in a distorted (longitudinally flattened) state, they agree very well with the *V. polystropha* specimens from the Lizard Springs formation of Trinidad. However, neither the Lizard Springs nor the Pale Greda specimens closely resemble Reuss' type figure of *Bulimina polystropha*, and perhaps a new specific name should be assigned to these specimens. The present author hesitates to take this step as he does not have access to Reuss' type material.

Cushman (1937, p. 11) states that many of the recent records of this species since the publication of Brady's *Challenger* report would best be referred to *V. scabra* (Williamson) or to *V. advena* Cushman. These species, and the *V. polystropha* of Brady's *Challenger* report, are more coarsely arenaceous than the Lizard Springs and the Pale Greda specimens of *V. polystropha*.

V. cf. *V. polystropha* as reported here is a common form and a good Pale Greda horizon marker.

Family VALVULINIDAE
Genus SCHENCKIELLA Thalmann, 1942
SCHENCKIELLA STAINFORTHI Weiss, n. sp.
Plate 2, figures 3–8

Test elongate, laterally compressed, initial portion polyserial, rapidly developing into a series of biserial chambers, and finally, in the fully mature forms, a uniserial stage; chambers of the early polyserial portion usually indistinct; with transmitted light, the early stage of some partially pyritized specimens appears to have an initial coil, followed by a very short section of seemingly irregularly arranged chambers which become biserial, then loosely biserial and more inflated, and finally uniserial; early sutures indistinct, later sutures depressed; wall finely arenaceous with a rough surface; aperture an elongate slit at the end of a short neck, at the inner margin of the biserial chambers and often keeping this tendency in the mature uniserial stage. Average length 0.90 mm.

Holotype from I. P. Co. well 3422, core depth 3162–3190 feet.

This highly variable species is unlike any *Schenckiella* (or *Listerella*) seen in the literature. It is a common species but a questionable Pale Greda index fossil due to rare occurrence of a somewhat similar elongated, arenaceous form in the stratigraphically younger Talara shale formation in the La Brea-Pariñas area.

Family MILIOLIDAE
Genus SPIROLOCULINA d'Orbigny, 1826
SPIROLOCULINA CRETACEA Reuss
Plate 1, figures 20, 21

(For references and figures see Cushman & Todd, 1944, Cushman Lab. Foram. Research Special Pub. no. 11, p. 3, pl. 2, figs. 1–4.)

This species is restricted to the Pale Greda formation on the La Brea-Pariñas property but is too rare to be considered a very useful index fossil.

Family TROCHAMMINIDAE
Genus TROCHAMMINA Parker & Jones, 1859
TROCHAMMINA DEPRESSA Lozo
Plate 1, figures 16, 17

Trochammina depressa Lozo, 1944, Am. Midland Naturalist, vol. 31, p. 552, pl. 2, figs. 4–5.

The very highly compressed Pale Greda specimens have a narrow, slightly thickened, almost keel-like, lobulate border. *T. depressa* is a good horizon marker for the Pale Greda formation in the central part of the La Brea-Pariñas property.

TROCHAMMINA GLOBIGERINIFORMIS (Parker & Jones)
Plate 1, figures 18, 19

(For references and figures see Cushman, 1946, U. S. Geol. Survey Prof. Paper 206, p. 51, pl. 15, figs. 8, 10, 11.)

A few slightly flattened forms in the Pale Greda material seem to be identifiable with this species. There are smaller, three to four chambered trochamminas in the Pale Greda which are texturally similar to *T. globigeriniformis* but are so distorted that accurate specific identification is virtually impossible. *T. globigeriniformis* is also found in the stratigraphically older Mal Paso formation in northwestern Peru.

TROCHAMMINA cf. T. ASAGAIENSIS Asano
Plate 1, figures 14, 15

?Trochammina asagaiensis ASANO, 1949, Jour. Paleontology, vol. 23, no. 5, p. 474, fig. 1 (2–4).

The Pale Greda specimens agree with the type description and figures in all respects but size. The diameter of Asano's species ranges to 1.00 mm. as compared to an average of 0.40 mm. for the Pale Greda specimens.

A fairly common species which should be a good horizon marker as it appears to be restricted to the Pale Greda formation in northwestern Peru.

Family LAGENIDAE
Genus ROBULUS Montfort, 1808

The representatives of this genus are rare to common in the Pale Greda formation. There are also numerous and variable species of *Robulus* in the stratigraphically younger formations on the La Brea-Pariñas property, and the Pale Greda species at best are only subdiagnostic as index fossils for the Pale Greda formation.

The criteria used in this report to differentiate the various *Robulus* species are as follows:

1. Overall dimensions—diameter and thickness of adult whorl.
2. Number of chambers in adult whorl.
3. Sutures—whether radial, tangential, limbate, flush, or raised.
4. Aperture—whether radiate, round, elongate, visible or not in early chambers.
5. Presence or absence of keel.

ROBULUS ALABAMENSIS Cushman
Plate 2, figures 11, 12

(For references and figures see Cushman, 1951, U. S. Geol. Survey Prof. Paper 232, p. 15, pl. 4, figs. 15, 16.)

The last chamber of the figured specimen is slightly more elongate than that of the average Pale Greda specimen.

ROBULUS YOUNGQUISTI Weiss, n. sp.
Plate 2, figures 13–16

Test small, with a narrow, thickened, almost keel-like periphery, slightly longer than broad, biumbonate, often with an irregular flap-like extension of the chamber wall covering the umbo on one side of the test; seven to nine chambers in the adult whorl, only little inflated, enlarging gradually as added; sutures limbate, flush, curved, slightly tangential to the umbo; wall smooth, vitreous, very finely perforate; aperture at the peripheral angle of the last chamber, round and radiate, visible in the earlier chambers.

Average dimensions: greater diameter, 0.75 mm.; lesser diameter, 0.50 mm.; thickness, 0.25 mm.

Some details, such as the sutural characteristics and the translucent apical angle, are best seen on a moistened test.

Holotype from I. P. Co. well 3387, core depth 1507–1542 feet.

This species is somewhat similar to *R. inornatus* (d'Orbigny) from the Eocene Cowlitz River beds (Beck, 1943, p. 595, pl. 104, figs. 1–4, 10, 14) but the latter species has a proportionately thicker test at the umbonal region and lacks the irregular flaplike extension over the umbo.

ROBULUS PSEUDOCULTRATUS Cole
Plate 2, figures 9, 10

Robulus pseudocultratus COLE, 1927, Bull. Am. Paleontology, vol. 14, no. 51, p. 19, pl. 1, fig. 5.

This species bears a very close resemblance to *Lenticulina rotulata* as figured by Cushman from the Upper Cretaceous of the Gulf Coast (Cushman, 1946, p. 56, pl. 19, figs. 1–7). However, the type specimen of *Lenticulina rotulata* (*Lenticulites rotulata* Lamarck) is not keeled.

R. pseudocultratus is also similar to *Robulina nitidissima* Reuss, but the latter species shows no thickening of the sutures toward the periphery.

ROBULUS cf. R. NAVARROENSIS
(Plummer)
Plate 2, figures 17–19

(For references and figures see Cushman, 1946, U. S. Geol. Survey Prof. Paper 206, p. 51, pl. 16, figs. 6–8.)

The Pale Greda forms seem identical to Mrs. Plummer's type specimen from the Navarro clay, but Cushman's figured specimens from the Corsicana marl have thicker sutures near the umbo.

On some of the Pale Greda specimens, the thin keel is worn smooth and is less distinct than that of the type specimen.

ROBULUS sp. A
Plate 2, figures 20, 21

Test very small, longer than broad, biumbonate, greatest thickness slightly below the median line; chambers indistinct, seven to eight in the last whorl, enlarging gradually as added; sutures indistinct, slightly curved, radiating from the umbos; wall vitreous, very finely perforate; aperture at the apical angle of the last chamber, round and radiate. Dimensions: greater diameter to 0.30 mm.; lesser diameter to 0.25 mm. The chambers and sutures are best observed on a moistened test.

ROBULUS sp. B
Plate 2, figures 22, 23

Test very small, almost circular in section view, biumbonate, periphery angular; seven chambers in the last whorl, the final three chambers enlarging more rapidly than the initial four, last chamber slightly inflated, with a short apertural face; sutures limbate,

very slightly curved, tangential to the clear calcite umbos; wall vitreous, finely perforate; aperture an elongate, protruding slit on the short apertural face, visible at times in the earlier chambers. Dimensions: Greater diameter to 0.30 mm.; lesser diameter to 0.27 mm.; thickness to 0.10 mm.

This species may be an immature or dwarfed form of *R. pseudocultratus* although they are not found in the same well cores in the Pale Greda formation.

Robulus spp. A and B occur in the sparsely fossiliferous facies of the Pale Greda formation. Because of their small size, they may be easily confused with immature forms of other species and are therefore difficult to use when correlating with well cuttings. However, when these minute *Robulus* species are present in an otherwise practically barren core, they are subdiagnostic for the Pale Greda formation.

Genus ASTACOLUS Montfort, 1808
ASTACOLUS PERUVIANUS Weiss, n. sp.
Plate 2, figures 24, 25

Test planispiral, compressed, partially evolute, with a thin keel; eight chambers in the final whorl, slightly inflated, enlarging gradually as added; sutures slightly curved, raised and limbate, thicker near the umbilical region; wall smooth, finely perforate; aperture radiate, slightly elongate, at the apex of the last chamber.

Holotype dimensions: Greater diameter, 0.65 mm.; lesser diameter, 0.50 mm.; thickness, 0.15 mm. Holotype from I.P.Co. well 3422, core depth 3241–3248 feet.

This species is very similar to *Planularia? arbenzi* Cushman and Renz from the Oligo-Miocene Agua Salada group of Venezueia. The queried generic designation of *Planularia? arbenzi* leads the writer to believe that the species also belongs in the *Astacolus* group. However, the sutures of *Planularia? arbenzi* thicken toward the periphery while those of *Astacolus peruvianus* are thicker at the umbilical region and tend to taper toward the periphery.

A. peruvianus is rare to common, and a good index fossil for the Pale Greda formation.

Genus MARGINULINA d'Orbigny, 1826
MARGINULINA ADUNCA (Franzenau)
AQUILINA Weiss, n. subsp.
Plate 3, figures 4, 5

Psecadium aduncum (Costa) GALLOWAY & MORREY, 1931, Jour. Paleontology, vol. 5, no. 4, p. 336, pl. 37, fig. 13 (not *Glandulina adunca* Costa, 1856).

Test small, initial portion coiled in a small, thin half-whorl; early chambers very little inflated and indistinct, adult chambers much inflated and rapidly increasing in size to a bulbous final chamber; early sutures indistinct, later sutures oblique and very slightly depressed; wall smooth, finely perforate; aperture terminal, produced, round and radiate, at the outer margin of the last chamber.

Holotype dimensions: greatest width 0.30 mm.; length 0.65 mm. Holotype from I.P.Co. well 3422, core depth 3162–3190 feet.

Cushman (1948, p. 228) states that the early chambers of the type *Psecadium* are biserial. *P. aduncum* (Costa) of Galloway and Morrey has an initial half-whorl, and on the basis of Galloway and Morrey's figured specimen, it appears that the radiate protruding aperture is on the outer margin of the last chamber. These characteristics would place the species in the genus *Marginulina*.

Franzenau (1894, p. 277, pl. 6, fig. 56a-b) also applied the trivial name *adunca* to a marginulinid form. The present author believes that Galloway and Morrey's and the Pale Greda form are subspecies of Franzenau's "*Cristellaria*" *adunca*, differing in having a more aquiline initial portion.

A rare form, limited to the Pale Greda formation on the La Brea-Pariñas property.

Genus DENTALINA d'Orbigny, 1826
DENTALINA COLEI Cushman & Dusenbury
Plate 2, figure 28

Dentalina colei CUSHMAN & DUSENBURY, 1934, Cushman Lab. Foram. Research Contr., vol. 10, p. 54, pl. 7, figs. 10–12.

A rare form which seems to be restricted to the Pale Greda formation in northwestern Peru.

DENTALINA EOCENICA Cushman
Plate 2, figure 29

(For references and figures see Cushman, 1951, U. S. Geol. Survey Prof. Paper 232, p. 22, pl. 6, figs. 30–33.)

This very rare Pale Greda species most closely resembles Mrs. Plummer's figured specimen from the Midway formation of Texas.

DENTALINA HEXACOSTATA Howe
Plate 3, figures 1, 2

Dentalina hexacostata HOWE, 1939, Louisiana, Dept. Conserv., Geol. Survey, Geol. Bull. no. 14, p. 44, pl. 5, fig. 13.

No whole tests were observed in the Pale Greda material, but rare to common fragments seem to fit this species very well.

D. hexacostata is also present in some of the younger formations on the La Brea-Pariñas property.

DENTALINA ALTERNATA (Jones)
Plate 2, figure 30

(For references and figures see Cushman, 1946 U. S. Geol. Survey Prof. Paper 206, p. 64 pl. 22, figs. 29–33.)

Very rare specimens in the Pale Greda formation seem to be typical of this species.

DENTALINA CONSOBRINA d'Orbigny(?)
Plate 3, figure 3

Dentalina consobrina D'ORBIGNY, 1846, Foram. Bass. Tert. Vienne, p. 46, pl. 2, figs. 1–3.
Dentalina consobrina d'Orbigny (?), CUSHMAN & DUSENBURY, 1934, Cushman Lab. Foram. Research Contr., vol. 10, p. 55, pl. 7, figs. 13–15.

A very rare form with chambers that rapidly tend to become elongate. The Pale Greda specimens most closely resemble *D. consobrina* in the literature, but more specimens would be necessary for an accurate generic and specific designation.

Genus NODOSARIA Lamarck, 1822
NODOSARIA ARUNDINEA Schwager
Plate 3, figure 6

Nodosaria arundinea SCHWAGER, 1866, Novara-Exped., Geol. Theil, vol. 2, pt. 2, p. 211, pl. 5, figs. 43–45;——GALLOWAY & MORREY, 1931, Jour. Paleontology, vol. 5, p. 337, pl. 37, fig. 15.

A very rare form which, as in most records of this species, consists only of the separate chambers of broken specimens.

The chambers of the Pale Greda specimens are also similar to the adult chambers of *Nodosaria*(?) *longiscata* d'Orbigny from the Paleocene of Arkansas (Cushman and Todd, 1946, p. 52, pl. 8, fig. 26).

NODOSARIA AFFINIS Reuss
Plate 3, figure 7

(For references and figures see Cushman, 1951, U. S. Geol. Survey Prof. Paper 232, p. 23, pl. 7, figs. 3–6.)

A fairly common form, present in both the Pale Greda and younger formations in northwestern Peru.

Genus FRONDICULARIA Defrance, 1824
FRONDICULARIA PALEGREDENSIS
Weiss, n. sp.
Plate 2, figures 26, 27

Test large, compressed, somewhat heart-shaped with the greatest breadth near the base and the sides convex; chambers chevron-shaped, numerous, increasing gradually in size as added, proloculum large and prominent, with three to five costae, one or two of which extend along the median line of the first three to five chambers: sutures indistinct, limbate, flush with the surface or very slightly raised; wall smooth; aperture terminal, slightly protruding, radiate.

Dimensions of holotype: length 2.00 mm.; greatest breadth 1.60 mm.; thickness 0.15 mm. Some broken specimens give evidence that the species may reach a length as great as 4.00 mm. Holotype from I.P.Co. well 3422, core depth 3162–3190 feet.

This species differs from *F. cordata* Roemer in having short costae and in lacking the sharply angular initial end; from *F. glabrans* Cushman in having costae on the pronounced proloculum and in the number of chambers; and from *F. microdisca* Reuss in lacking the long median rib.

The figured and described specimens are very probably the megalospheric form of the species, but no specimens with an initial coil or a markedly smaller proloculum were observed.

This is a rare to common Pale Greda species and a very useful index fossil.

Genus PSEUDOGLANDULINA Cushman, 1929

PSEUDOGLANDULINA MANIFESTA (Reuss)
Plate 3, figures 8, 9

(For references and figures see Cushman, 1951, U. S. Geol. Survey Prof. Paper 232, p. 25, pl. 7, figs. 16, 17.)

This long-ranging species is fairly common throughout the Tertiary stratigraphic column in the La Brea-Pariñas area.

Genus LAGENA Walker & Boys, 1784

This genus is represented in the Pale Greda material by only four specimens—with each specimen specifically distinct from the others.

LAGENA SULCATA (Walker & Jacob) var. SEMIINTERRUPTA W. Berry
Plate 3, figure 10

(For references and figures see Cushman, 1946, U. S. Geol. Survey Prof. Paper 206, p. 94, pl. 39, figs. 18–21.)

LAGENA ASPERA Reuss
Plate 3, figure 11

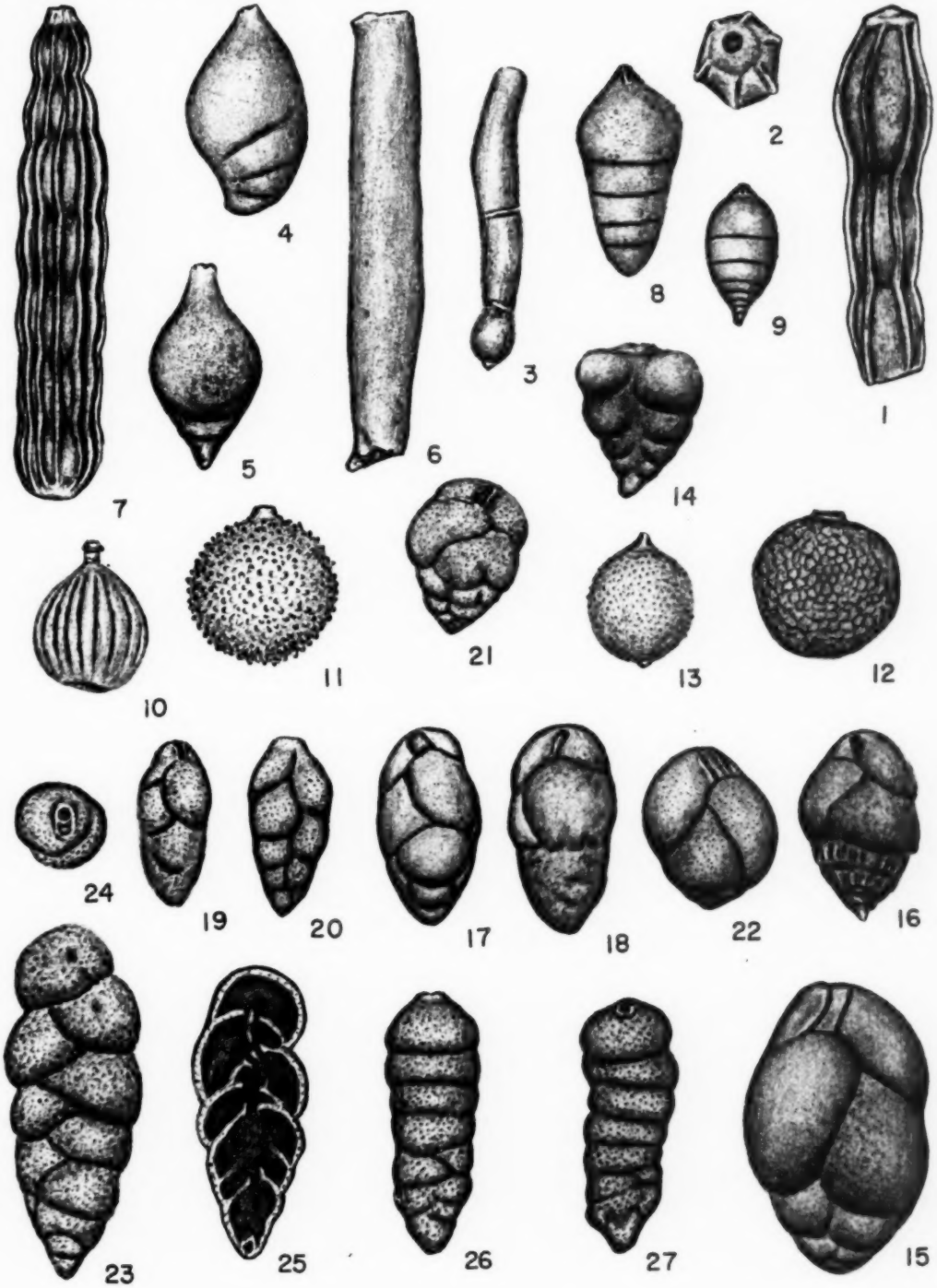
Lagena aspera REUSS, 1862, K. Akad. Wiss. Wien, Math.-Naturw. Cl., Sitzber., Bd. 44, Abth. 1, p. 305, pl. 1, fig. 5.

LAGENA cf. L. HEXAGONA (Williamson)
Plate 3, figure 12

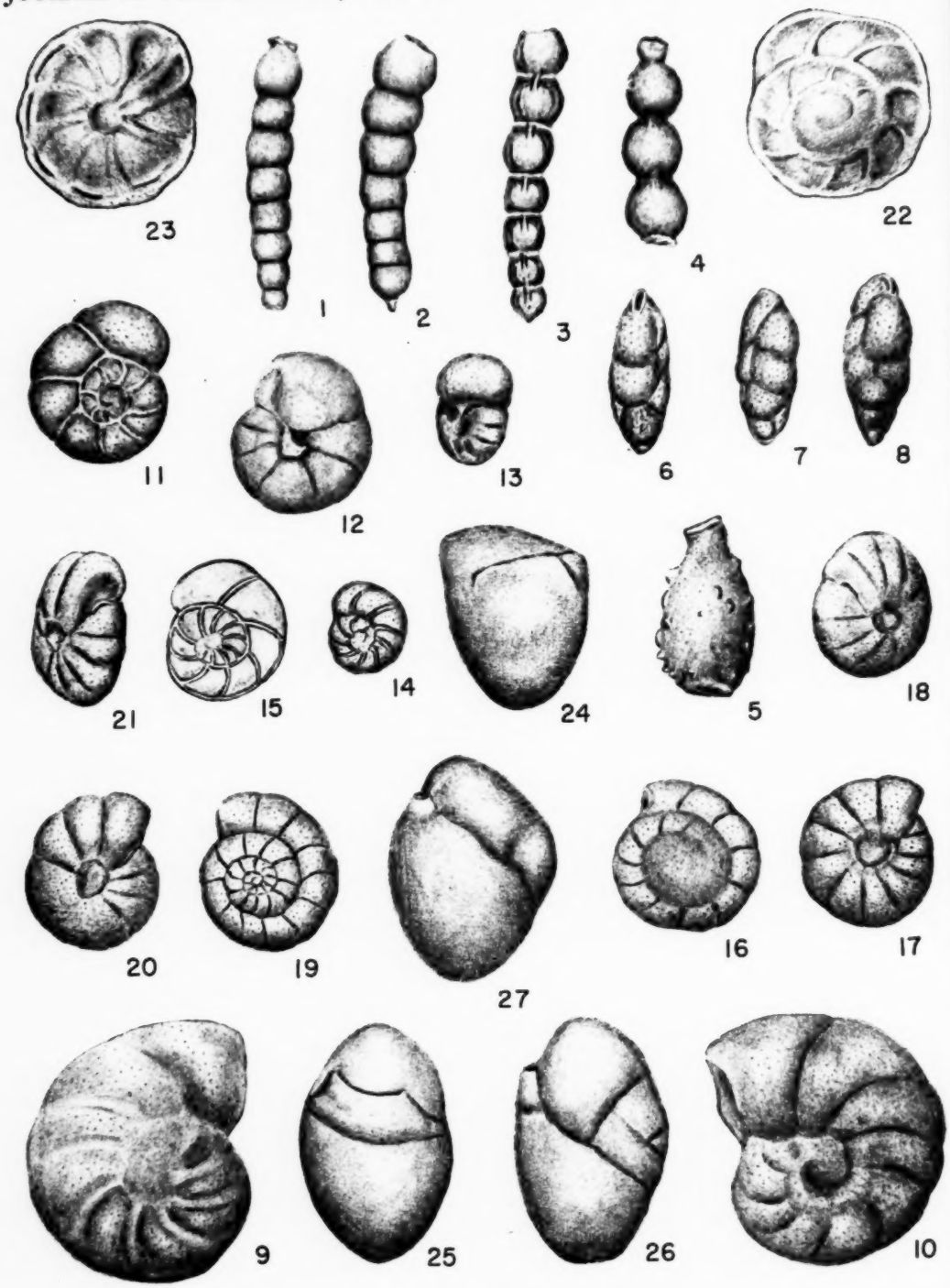
?Entosolenia squamosa (Montagu) var. γ, *hexagona* WILLIAMSON, 1848, Annals and Mag. Nat. Hist., ser. 2, vol. 1, p. 20, pl. 2, fig. 23.
?Lagena hexagona (Williamson), FRIZZELL, 1943, Jour. Paleontology, vol. 17, no. 4, p. 348, pl. 56, fig. 26.

EXPLANATION OF PLATE 3

FIGS. *1, 2—Dentalina hexacostata* Howe, ×60. I.P.Co. well 3422, core depth 3162–3190′. (p. 11)
3—Dentalina consobrina d'Orbigny(?), ×40. I.P.Co. well 3387, core depth 1507–1542′. (p. 11)
4, 5—Marginulina adunca (Franzenau) *aquilina* Weiss, n. subsp., ×60. Holotype. I.P.Co. well 3422, core depth 3162–3190′. (p. 10)
6—Nodosaria arundinea Schwager, ×85. I.P.Co. well 3387, core depth 1507–1542′. (p. 11)
7—Nodosaria affinis Reuss, ×30. I.P.Co. well 3422, core depth 3162–3190′. (p. 11)
8, 9—Pseudoglandulina manifesta (Reuss), ×60. *8*, megalospheric specimen; *9*, young microspheric specimen. I.P.Co. well 3422, core depth 3142–3248′. (p. 12)
10—Lagena sulcata (Walker & Jacob) var. *semiinterrupta* W. Berry, ×85. I.P.Co. well 3387, core depth 1507–1542′. (p. 12)
11—Lagena aspera Reuss, ×85. I.P.Co. well 3387, core depth 1507–1542′. (p. 12)
12—Lagena cf. *L. hexagona* (Williamson), ×85. I.P.Co. well 3422, core depth 3241–3248′. (p. 12)
13—Lagena sp., ×85. I.P.Co. well 3422, core depth 3241–3248′. (p. 13)
14—Gümbelina cf. *G. trinitatensis* Cushman & Renz, ×85. I.P.Co. well 4200, core depth 7672–7688′. (p. 13)
15—Bulimina debilis Martin, ×85. I.P.Co. well 3422, core depth 3162–3190′. (p. 13)
16—Bulimina arkadelphiana Cushman & Parker var. *midwayensis* Cushman & Parker, ×85. I.P.Co. well 3387, core depth 1507–1542′ (p. 13)
17—Bulimina schencki Beck, ×85. I.P.Co. well 4430, core depth 5074–5083′. (p. 13)
18—Bulimina crenata Weiss, n. sp., ×85. Holotype. I.P.Co. well 3387, core depth 1507–1542′. (p. 14)
19, 20—Bulimina virguliniformis Weiss, n. sp., ×85. *19*, holotype, I.P.Co. well 4200, core depth 7672–7688′; *20*, I.P.Co. well 3387, core depth 1507–1542′. (p. 14)
21—Bulimina fissura Weiss, n. sp., ×85. Holotype, I.P.Co. well 3422, core depth 3241–3248′. (p. 14)
22—Bulimina cf. *B. pyrula* d'Orbigny, ×85. I.P.Co. well 3422, core depth 3241–3248′. (p. 14)
23–25—Siphogenerina eleganta Plummer, ×85. Three specimens, I.P.Co. well 3387, core depth 1507–1542′. *25*, section view of pyritized specimen showing portions of the internal siphon. (p. 14)
26, 27—Siphogenerina brevispinosa (Cushman), ×85. Two specimens, I.P.Co. well 3422, core depth 3162–3190′. (p. 15)



Weiss, Paleocene Foraminifera, Peru



Weiss, Paleocene Foraminifera, Peru

The reticulate surface ornamentation of the Pale Greda specimen is smaller than that figured by Williamson or Frizzell.

LAGENA sp.
Plate 3, figure 13

This small, apiculate, conspicuously perforate form is somewhat similar to *Entosolenia* cf. *E. apiculata* (Reuss) (Cushman, 1951, p. 42, pl. 9, fig. 7), but no entosolenian aperture was observed.

Family HETEROHELICIDAE
Genus GÜMBELINA Egger, 1899
GÜMBELINA cf. G. TRINITATENSIS
Cushman & Renz
Plate 3, figure 14

?Gümbelina trinitatensis CUSHMAN & RENZ, 1942, Cushman Lab. Foram. Research Contr., vol. 18, p. 8, pl. 2, fig. 8 a–b.

A single, partially broken specimen seems to be referable to this species.

Family BULIMINIDAE
Genus BULIMINA d'Orbigny, 1826
BULIMINA DEBILIS Martin
Plate 3, figure 15

Bulimina debilis MARTIN, 1943, Stanford Univ. Publ., Univ. Ser., Geol. Sci., vol. 3, no. 3, p. 110, pl. 6, fig. 1;——CUSHMAN & STONE, 1947, Cushman Lab. Foram. Research Special Pub. 20, p. 14, pl. 2, fig. 15.

A rare form in the Pale Greda which is also present in the overlying younger formations on the La Brea-Pariñas property.

BULIMINA ARKADELPHIANA Cushman & Parker var. MIDWAYENSIS Cushman & Parker
Plate 3, figure 16

Bulimina arkadelphiana Cushman & Parker var. *midwayensis* CUSHMAN & PARKER, 1936, Cushman Lab. Foram. Research Contr., vol. 12, p. 42, pl. 7, figs. 9, 10.
Bulimina aculeata d'Orbigny, PLUMMER (not d'Orbigny), 1927, Univ. Texas Bull. 2644, p. 73, pl. 4, fig. 3.

Of the many semicostate species of *Bulimina* in the literature, the Pale Greda forms most closely resemble this species. It is also very closely related to *B. denticulata* Cushman and Parker from the Martinez shale of California, but differs slightly in that the aperture of *B. denticulata* does not reach the suture between the two previous chambers. A somewhat similar species, referred to as *B. stalacta* Cushman and Parker (Cushman and Stone, 1947, p. 13, pl. 2, fig. 12), occurs in the upper Eocene of northwestern Peru.

BULIMINA SCHENCKI Beck
Plate 3, figure 17

Bulimina schencki BECK, 1943, Jour. Paleontology,

EXPLANATION OF PLATE 4

FIGS. *1–3—Stilostomella verneuili* (d'Orbigny), ×60. Three specimens. *1*, microspheric form; *2*, megalospheric form; *3*, section view. I.P.Co. well 3422, core depth 3162–3190′. (p. 15)
4—Stilostomella abyssorum (Brady)? var. *gracillima* (Cushman & Jarvis), ×60. I.P.Co. well 3422, core depth 3162–3190′. (p. 15)
5—Stilostomella stephensoni (Cushman) var. *speciosa* (Cushman), ×85. I.P.Co. well 3422, core depth 3162–3190′. (p. 15)
6–8—Virgulina dorreeni Weiss, n. sp., ×85. *6*, *7*, holotype; *8*, paratype. I.P.Co. well 4200, core depth 7672–7688′. (p. 16)
9, *10—Discorbis* sp., ×85. I.P.Co. well 3387, core depth 1507–1542′. (p. 16)
11–15—Valvulineria palegredensis Weiss, n. sp., ×60. *11*, *12*, holotype, I.P.Co. well 3422, core depth 3241–3248′; *13*, apertural view of another specimen; *14*, young specimen; *15*, section view; I.P.Co. well 3387, core depth 1507–1542′. (p. 16)
16–18—Gyroidina depressa (Alth) *parvula* Weiss, n. subsp., ×85. Holotype. I.P.Co. well 3387, core depth 1507–1542′. (p. 16)
19–21—Gyroidina sp., ×85. I.P.Co. well 3387, core depth 3241–3248′. (p. 17)
22, *23—Epistomina eocenica* Cushman & M. A. Hanna, ×60. I.P.Co. well 3387, core depth 1507–1542′. (p. 17)
24—Allomorphina sp., ×85. I.P.Co. well 3422, core depth 3162–3190′. (p. 17)
25–27—Chilostomella polsoni Weiss n. sp., ×85. *25*, *26*, holotype. I.P.Co. well 3387, core depth 1507–1542′; *27*, I.P.Co. well 4200, core depth 7672–7688′. (p. 17)

vol. 17, no. 6, p. 605, pl. 107, figs. 28, 33.
Bulimina capitata Yokoyama (?), CUSHMAN & DUSENBURY (not Yokoyama), 1934, Cushman Lab. Foram. Research Contr., vol. 10, p. 61, pl. 8, fig. 10 a–b.

The Pale Greda specimens fit Beck's figures and description of the Cowlitz River form (Eocene) very closely.

B. schencki is a rare form, found in the southern part of the La Brea-Pariñas area.

BULIMINA CRENATA Weiss, n. sp.
Plate 3, figure 18

Test small, about two to two and one-half times as long as broad, bluntly tapering toward the proloculum, composed of three to four whorls, with the last whorl making up half the test; early chambers and sutures indistinct, adult chambers slightly inflated, sutures depresed, with faint reentrants and lobular processes; wall smooth except for the faint sutural reentrants, conspicuously perforate; aperture elongate, from the apex of the last chamber to the suture between the last and penultimate chambers.

Holotype dimensions: length 0.35 mm.; greatest width 0.15 mm. Holotype from I.P.Co. well 3387, core depth 1507–1542 feet.

A rare form in the Pale Greda formation. It differs from *B. aspera* Cushman and Parker (1940, p. 44, pl. 8, figs. 18, 19) in having larger final chambers, sutural reentrants, and in lacking the basal spine.

BULIMINA VIRGULINIFORMIS Weiss, n. sp.
Plate, 3 figures 19, 20

Test very small, fusiform, composed of three whorls with the last whorl making up about half the test; early chambers and sutures usually indistinct and finely papillate, the papillae often suggesting a linear arrangement; in the adult whorl the sutures are depressed, the chambers slightly inflated and the wall fairly coarsely perforate and smooth; aperture an almost terminal, elongate virguline-like slit with a slight lip.

Holotype dimensions: length 0.25 mm.; greatest width 0.10 mm. Holotype from I. P. Co. well 4200, core depth 7672–7688 feet.

This species differs from *B. elongata* var. *tenera* Reuss (Cushman and Parker, 1937, p. 50, pl. 7, fig. 5) in its smaller size, apertural characteristics, and in the papillate early chambers.

Rare in the Pale Greda formation, and also present in the stratigraphically older Mal Paso formation on the La Brea-Pariñas property.

BULIMINA FISSURA Weiss, n. sp.
Plate 3, figure 21

Test very small, composed of three whorls, with the last whorl making up half the test, tapering to a subacute initial end; chambers slightly inflated, enlarging rapidly, sutures distinct, depressed, with one sutural reentrant or cleft on each chamber; wall smooth, finely perforate; aperture a broad slit in a depression on the last septal face, with a very slight lip.

Holotype dimensions: length 0.25 mm.; greatest width 0.15 mm. Holotype from I. P. Co. well 3422, core depth 3241–3248 feet.

This species resembles *B. reussi* Morrow var. *navarroensis* Cushman and Parker (1935, p. 100, pl. 15, fig. 11 a-b) but differs in having a broader aperture and sutural reentrants.

Rare in the Pale Greda in the central part of the La Brea-Pariñas area.

BULIMINA cf. B. PYRULA d'Orbigny
Plate 3, figure 22

?Bulimina pyrula D'ORBIGNY, 1846, Foram. Foss. Bass. Tert. Vienne, p. 184, pl. 11, figs. 9, 10; ——CUSHMAN & PARKER, 1937, Cushman Lab. Foram. Research Contr., vol. 13, p. 46, pl. 6, fig. 1.

A single partially pyritized specimen, which may be compared with this species.

Genus SIPHOGENERINA
Schlumberger, 1883
SIPHOGENERINA ELEGANTA
Plummer
Plate 3, figures 23–25

Siphogenerina eleganta PLUMMER, 1927, Univ. Texas Bull. 2644, p. 126, pl. 8, fig. 1
Siphogenerinoides eleganta (Plummer), CUSHMAN, 1940, Cushman Lab. Foram. Research Contr., vol. 16, p. 66, pl. 11, fig. 17;——CUSHMAN & TODD, 1946, Cushman Lab. Foram. Research Contr., vol. 22, p. 59, pl. 10, fig. 18.

The Pale Greda specimens are identical

with the aspinose forms figured by Mrs. Plummer.

Stone (1946, p. 466, fig. 2) describes the siphon-apertural character of the genus *Siphogenerina* as follows: "Slightly below the lip of the aperture, and completely encircled by this lip, is a small circular opening, which is the uppermost end of the internal siphon present in all species I have seen of this genus."

In his discussion of the morphology of *Siphogenerinoides*, Stone states that *Siphogenerinoides eleganta* (Plummer) and *S. brevispinosa* Cushman have modified siphogenerinoid apertures, and that they might perhaps be considered a subgenus of *Siphogenerinoides*. Neither of these forms has a well developed neck, but close scrutiny of the relationship of the siphon to the aperture of well-preserved specimens clearly indicates the siphon to be completely within the apertural lip. If this, then, is the decisive generic characteristic, it would appear that both these species belong in the genus *Siphogenerina*.

The initial end of the Pale Greda and Texas Midway specimens has a biserial chamber arrangement. It seems to the writer that these forms represent megalospheric specimens of the species, not microspheric as was tentatively proposed by Mrs. Plummer. The specimen figured by Cushman from the Midway of Alabama is initially triserial and very probably represents the microspheric form.

S. eleganta is rare to common, restricted to the Pale Greda formation in the central part of the La Brea-Pariñas area.

SIPHOGENERINA BREVISPINOSA (Cushman)
Plate 3, figures 26, 27

Siphogenerinoides brevispinosa CUSHMAN, 1939, Cushman Lab. Foram. Research Contr., vol. 15, p. 92, pl. 16, fig. 7.

As was discussed in the previously described species (*Siphogenerina eleganta*), the relationship of the aperture to the siphon indicates that this species belongs in the genus *Siphogenerina*.

While many of the Pale Greda specimens are covered with the very short spines referred to by Cushman in his original description, the surface of a number of specimens in our material would best be described as coarsely perforate and roughened.

S. brevispinosa is fairly common and a good horizon marker for the Pale Greda formation in the central part of the La Brea-Pariñas area.

Genus STILOSTOMELLA Guppy, 1894

Stainforth (1952a, pp. 6–14, fig. 1, and 1952b, p. 9) has recently done much to clarify the confusion in the literature on the classification of uniserial calcareous Foraminifera with non-radiate apertures. On the basis of his work, those forms with tubular apertures, phialine lips, and internal tooth-like processes are included in the genus *Stilostomella*.

STILOSTOMELLA VERNFUILI (d'Orbigny)
Plate 4, figures 1–3

(For earlier references see Cushman & Todd, 1945, Cushman Lab. Foram. Research Special Pub. 15, p. 54, pl. 8, fig. 9.)

Dentalina vagina Stache (?), CUSHMAN & DUSENBURY, 1934, Cushman Lab. Foram. Research Contr., vol. 10, p. 55, pl. 7, fig. 16.

Ellipsonodosaria cf. *E. cocoaensis* (Cushman), BECK, 1943, Jour. Paleontology, vol. 17, p. 608, pl. 108, fig. 10.

Ellipsonodosaria verneuili (d'Orbigny), CUSHMAN & RENZ, 1948, Cushman Lab. Foram. Research Special Pub. 24, p. 31, pl. 6, fig. 8; ——CUSHMAN & STAINFORTH, 1951, Jour. Paleontology, vol. 25, p. 156, pl. 27, figs. 3–4.

This species is rare to common in both the Pale Greda and stratigraphically younger formations on the La Brea-Pariñas property.

STILOSTOMELLA ABYSSORUM (Brady)? var. GRACILLIMA (Cushman & Jarvis)
Plate 4, figure 4

Ellipsonodosaria nuttalli Cushman & Jarvis var. *gracillima* CUSHMAN & JARVIS, 1934, Cushman Lab. Foram. Research Contr., vol. 10, p. 72, pl. 10, fig. 7 a–b;——CUSHMAN & STAINFORTH, 1951, Jour. Paleontology, vol. 25, p. 156, pl. 26, fig. 65.

A rare form in the Pale Greda formation which seems to fit this species very well.

STILOSTOMELLA STEPHENSONI (Cushman) var. SPECIOSA (Cushman)
Plate 4, figure 5

Ellipsonodosaria stephensoni Cushman var.

speciosa CUSHMAN, 1938, Cushman Lab. Foram. Research Contr., vol. 14, p. 47, pl. 8, fig. 3.

Rare single chambers from broken specimens in the Pale Greda material agree very well with the type figure and description.

Genus VIRGULINA d'Orbigny, 1826
VIRGULINA DORREENI Weiss, n. sp.
Plate 4, figures 6–8

Test very small, about three times as long as broad, fusiform, initial triserial portion almost round in section, adult twisted biserial portion more compressed; early chambers indistinct, later biserial chambers larger, more inflated, comprising about two-thirds of the test, sutures distinct, depressed; wall conspicuously perforate, with the perforations often arranged as longitudinal striae: aperture almost terminal, elongate, with a thickened lip, extending down the inner margin of the last chamber.

Average dimensions: length 0.25 mm.; greatest width 0.08 mm. Holotype from I. P. Co. well 4200, core depth 7672–7688 feet.

Although this is a very small species and therefore difficult to employ as a guide fossil in routine well work, it is a good Pale Greda horizon marker with a greater horizontal extent than most of the Pale Greda Foraminifera.

The small size, relatively more elongate chambers, and longitudinal striations serve to differentiate this species from *V. diversa* Cushman and Stone, found in the younger Chacra formation on the La Brea-Pariñas property.

Family ROTALIIDAE
Genus DISCORBIS Lamarck, 1804
DISCORBIS sp.
Plate 4, figures 9, 10

This species is very similar to a new but as yet unnamed species described by Benton Stone from the Quemada zone of the Talara shale formation on the La Brea-Pariñas property. The Pale Greda specimens are usually smaller than the typical Quemada zone adult forms but indistinguishable from immature Quemada specimens. Specimens from both formations occasionally show a tendency toward raised dorsal sutures.

Genus VALVULINERIA Cushman, 1926
VALVULINERIA PALEGREDENSIS Weiss, n. sp.
Plate 4, figures 11–15

Test small, consisting of two to two and one-half whorls, slightly longer than broad, dorsal side flattened, vertral convex and umbilicate, periphery broadly rounded, smooth in the young form, becoming lobulate with the addition of the adult chambers; initial whorl with eight to nine chambers, of uniform shape, only slightly inflated, increasing gradually in size as added, adult whorl with six to seven chambers, the last few highly inflated and increasing rapidly in size; the reduction in numbers per whorl is caused by a gradual change in shape: they are prolonged radially in the young form but tangentially in the adult (see fig. 15); sutures of the initial whorl raised, limbate, radial and slightly curved, becoming depressed, non-limbate, straight, and increasingly tangential in the adult; spiral suture in the young flush with the surface, depressed in the adult; wall smooth, finely perforate; aperture a low arched slit at the base of the last septal face, extending about half way from the open umbilicus toward the periphery, often partially covered by a small ventral extension of the last chamber.

Dimensions of holotype: length 0.50 mm.; breadth 0.40 mm.; thickness 0.25 mm. Holotype from I. P. Co. well 3422, core depth 3241–3248 feet.

This species is common to abundant in the central part of the La Brea-Pariñas area and is an excellent Pale Greda index fossil. It is closely related to *V. ripleyensis* Sandidge (1932, p. 281, pl. 43, figs. 4–6) which differs from *V. palegredensis* in its tendency for the more globular final chambers to overlap, and in its curved final sutures.

Genus GYROIDINA d'Orbigny, 1826
GYROIDINA DEPRESSA (Alth) PARVULA
Weiss, n. subsp.
Plate 4, figures 16–18

Test very small, biconvex, the ventral side more so than the dorsal, periphery bluntly acute, umbilicate, sometimes with a thickened rim of shell material around the umbilicus; early chambers indistinct, 10 to 11 chambers in the final whorl, enlarging

very gradually as added; early dorsal sutures indistinct, dorsal sutures of final whorl slightly depressed, straight to very slightly curved, ventral sutures depressed, straight, radial; wall smooth, vitreous, finely perforate; aperture a low arched opening midway between the periphery and the umbilicus.

Holotype dimensions: diameter 0.22 mm. (usually smaller); thickness 0.10 mm. Holotype from I. P. Co. well 3387, core depth 1507–1542 feet.

This species clearly belongs in the variable *depressa* group. It appears to be most closely related to *G. depressa* var. *colombiana* Cushman and Hedberg from the Upper Cretaceous of Colombia, but differs in its smaller size and apertural character.

G. depressa parvula is a rare form which seems to be restricted to the Pale Greda formation in the La Brea-Pariñas area.

GYROIDINA sp.
Plate 4, figures 19–21

A single specimen, which can be distinguished by its evenly biconvex test and apertural lip, was found in the Pale Greda material. There is a strong similarity between this form and *G. scita* Cushman and Stone (1949, p. 56, pl. 10, fig. 12), but more specimens would be necessary for accurate identification.

Genus EPISTOMINA Terquem, 1883
EPISTOMINA EOCENICA Cushman & M. A. Hanna
Plate 4, figures 22, 23

(For references and figures see Cushman, 1951, U. S. Geol. Survey Prof. Paper 232, p. 55, pl. 15, figs. 13, 14.)

The Pale Greda forms of this widely reported species usually have a worn surface which makes the broadly limbate sutures of the type specimen difficult to see. The periphery is subacute and there is often a dorsal umbo of clear calcite over the first two whorls. Both of these characteristics are emphasized at times by dorso-ventral compression.

E. eocenica is rare to common in the Pale Greda formation and is also present in some of the younger formations in northwestern Peru.

Family CHILOSTOMELLIDAE
Genus ALLOMORPHINA Reuss, 1850
ALLOMORPHINA sp.
Plate 4, figure 24

Two specimens of this typically trigonal form were found in the Pale Greda material. They compare favorably with *A. macrostoma* Karrer from the upper Eocene of Venezuela (Nuttall, 1935, p. 129, pl. 15, fig. 28).

Genus CHILOSTOMELLA Reuss, 1850
CHILOSTOMELLA POLSONI Weiss, n. sp.
Plate 4, figures 25–27

Test small, almost twice as long as broad, aboral end of the penultimate chamber slightly more acute than that of the last chamber; the last chamber almost completely embraces the ventral side of the test, but covers less than half of the dorsal, exposing the early whorl which is sometimes developed into a prominent hump; early sutures usually not discernible, last suture depressed; wall smooth, finely perforate; aperture a narrow, slightly curved, ventral opening with a wide, thin, sometimes irregularly serrated lip.

Holotype dimensions: length 0.40 mm.; width 0.25 mm. Holotype from I. P. Co. well 3387, core depth 1507–1542 feet.

This species differs from *C. cylindroides* Reuss in being smaller and less robust, and from *C. mexicana* Nuttall var. *seriata* Cushman and Stone in its smaller size and narrower, less serrate apertural lip.

Chilostomella polsoni is a rare form in the Pale Greda formation and also in some of the younger (Eocene) formations in the La Brea-Pariñas area.

Family GLOBIGERINIDAE
Genus GLOBIGERINA d'Orbigny, 1826

Although the Pale Greda species of this genus are variable, the variations revolve around a few dominant forms. These species may be found in the literature and appear to have had a widespread distribution during Paleocene-Eocene time. None of the Pale Greda *Globigerina* species are reliable as horizon markers as all the common, identifiable forms are present in the strati-

graphically younger Chacra formation on the La Brea-Pariñas property.

GLOBIGERINA PSEUDOTRILOBA White
Plate 5, figures 1–3

Globigerina pseudotriloba WHITE, 1928, Jour. Paleontology, vol. 2, p. 194, pl. 27, fig. 17.

A small globular three-chambered species. Rare in the Pale Greda formation.

GLOBIGERINA EOCAENICA Terquem
Plate 5, figures 4–6

Globigerina eocaenica TERQUEM, 1882, Mém. Soc. Géol. France, ser. 3, vol. 2, no. 3, p. 86, pl. 9, fig. 4.

A common Pale Greda species, more compressed and less lobulate than *G. pseudotriloba*.

GLOBIGERINA TRILOCULINOIDES Plummer
Plate 5, figures 7–9

(For references and figures see Cushman, 1951, U. S. Geol. Survey Prof. Paper 232, p. 60, pl. 17, figs. 10, 11.)

This small, three-and-one-half-chambered species with globular, dorsally rounded chambers is common in the Pale Greda material. Rare specimens have the apertural flap as figured by Mrs. Plummer (1926, p. 134, pl. 8, fig. 10).

GLOBIGERINA cf. G. WILSONI Cole
Plate 5, figures 10–12

?Globigerina wilsoni COLE, 1927, Bull. Am. Paleontology, vol. 14, no. 51, p. 34, pl. 4, figs. 8, 9.

A small five-chambered form, with chambers less globular than *G. pseudobulloides*. Very rare in the Pale Greda formation.

GLOBIGERINA cf. G. TRILOCULARIS d'Orbigny
Plate 5, figures 13–15

?Globigerina trilocularis D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 277, no. 2;——DESHAYES, 1832, Ency. Méth., Hist. Nat. des Vers, vol. 2, pt. 2, p. 170;——FORNASINI, 1897, Rend. R. Accad. Sci. Ist. Bologna, n.s., vol. 2, fasc. 1, pp. 12–13, pl. 1, figs. 6–7; p. 12, text fig.
Globigerina trilocularis d'Orbigny, BANDY, 1944, Jour. Paleontology, vol. 18, p. 376, pl. 62, figs. 7a, b.

A single globular specimen, differing from all other Pale Greda globigerinid forms in having a high trochoid spire, seems to agree with this species.

GLOBIGERINA STONEI Weiss, n. sp.
Plate 5, figures 16–21

Globigerina cf. *G. pseudobulloides* Plummer, CUSHMAN & STONE, 1949, Cushman Lab. Foram. Research Contr., vol. 25, p. 57, pl. 10, fig. 15.

Cushman and Stone's well-figured specimen was reported from the Chacra formation of the La Brea-Pariñas property, where it is sometimes larger than the Pale Greda holotype. However, *G. pseudobulloides* Plummer is composed of five and sometimes six highly ventricose chambers and does not agree closely with the Pale Greda or Chacra forms.

The typical *G. stonei* may be described as follows:

Test small, consisting of about two whorls, dorsal side flattened, ventral convex with a large, open umbilicus, periphery rounded and lobulate; four chambers in the last whorl, enlarging gradually as added, subglobular, with a slight ventral taper; sutures depressed, distinct; wall conspicuously perforate and covered with fine papillae; aperture an arched slit at the base of the last septal face, extending from the open umbilicus toward the periphery, often with a slight lip. Greatest diameter of holotype 0.25 mm. Holotype from I. P. Co. well 3297, core depth 1561–1579 feet.

There are also more compressed variants of *G. stonei* present in both the Chacra and Pale Greda formations. These range through all intermediate stages toward the end form which differs from the typical *G. stonei* in its more tightly coiled globorotalid test with three and one-half to four more appressed chambers, a less lobulate periphery, and a smaller umbilicus.

Both end types and all transitional forms of *G. stonei* are fairly common throughout the Pale Greda formation.

Family GLOBOROTALIIDAE
Genus GLOBOROTALIA Cushman, 1927
GLOBOROTALIA WHITEI Weiss, n. sp.
Plate 6, figures 1–3

Globigerina crassaformis Galloway & Wissler, WHITE, 1928, Jour. Paleontology, vol. 2, p. 193, pl. 27, fig. 14.

Globorotalia crassaformis (Galloway & Wissler), NUTTALL, 1935, Jour. Paleontology, vol. 9, p. 130, pl. 15, figs. 21, 29.

Test small, composed of two whorls, dorsal side flat, ventral convex with a small shallow umbilicus, periphery bluntly angular; chambers appressed, four to a whorl, tapering ventrally, the initial three of the last whorl subequal in size and shape; sutures radial, distinct, depressed, ventrally suggesting an X-shaped pattern; wall conspicuously perforate and papillate; aperture a narrow, arched slit with a slight lip about midway between the shallow umbilicus and the periphery, often indistinct. Diameter of holotype 0.25 mm. Holotype from I. P. Co. well 4200, core depth 7672–7688 feet.

This species is somewhat similar dorsoventrally to *G. crassula* Cushman and Stewart but differs in its less angular periphery.

A very similar four-chambered form with a shallow umbilicus and appressed chambers occurs rarely in the stratigraphically younger Chacra formation on the La Brea-Pariñas property.

GLOBOROTALIA CRASSATA (Cushman) var. AEQUA Cushman & Renz
Plate 6, figures 4–6

Globorotalia crassata (Cushman) var. *aequa* CUSHMAN & RENZ, 1942, Cushman Lab. Foram. Research Contr., vol. 18, p. 12, pl. 3, fig. 3;——CUSHMAN & BERMUDEZ, 1949, Cushman Lab. Foram. Research Contr., vol. 25, p. 37, pl. 7, figs. 7–9.

This species is fairly common in the Pale Greda formation and is an excellent index fossil.

GLOBOROTALIA WILCOXENSIS Cushman & Ponton
Plate 6, figures 7–9

Globorotalia wilcoxensis CUSHMAN & PONTON, 1932, Cushman Lab. Foram. Research Contr., vol. 8, p. 71, pl. 9, figs. 10 a–c;——CUSHMAN & BERMUDEZ, 1949, Cushman Lab. Foram. Research Contr., vol. 25, p. 39, pl. 7, figs. 16–18.

Very rare specimens which seem to fit this species occur in the Pale Greda formation. The angular periphery of the last-formed chamber differentiates this species from somewhat similar four- to four-and-one-half-chambered globorotalid forms in the Chacra formation on the La Brea-Pariñas property.

Family ANOMALINIDAE
Genus ANOMALINA d'Orbigny, 1826
ANOMALINA WELLERI (Plummer)
Plate 6, figures 10–12

(For references and figures see Cushman, 1951, U. S. Geol. Survey Prof. Paper 232, p. 63, pl. 18, fig. 12.)

This small species differs from the immature *Valvulineria palegredensis* in having more chambers per whorl, a sharper periphery, an umbilical ridge, and different apertural characteristics.

A. welleri is a rare species which appears to be restricted to the Pale Greda formation in the northern part of the La Brea-Pariñas area.

Genus CIBICIDES Montfort, 1808
CIBICIDES COONENSIS (W. Berry)
Plate 6, figures 13–15

(For references and figures see Cushman, 1946, U. S. Geol. Survey Prof. Paper 206, p. 160, pl. 65, fig. 15.)

The swollen ventral chambers of this species (sometimes abnormally so in the Pale Greda specimens) have an *Anomalina*-like appearance, but due to the silt-like extension of the aperture to the dorsal, more evolute side of the test, the present author agrees with Thalmann (1941, p. 679) in placing the species in the genus *Cibicides*.

C. sassei Cole (Cushman & Dusenbury, 1934, p. 64, pl. 9, figs. 5a-c) lacks the ventral plug of the type *C. sassei* Cole (1927, p. 35, pl. 4, figs. 10–11) and probably should be included in *C. coonensis*.

C. coonensis is fairly common and seems to be restricted to the Pale Greda formation on the La Brea-Pariñas property.

CIBICIDES cf. C. FORTUNATUS Martin
Plate 6, figures 16, 17

?Cibicides fortunatus MARTIN, 1943, Stanford Univ., Publ., Univ. Ser., Geol. Sci., vol. 3, no. 3, p. 121, pl. 8, fig. 5.

The Pale Greda specimens are very rare and are usually lacking the last chamber. They compare favorably with the type from

the Lodo formation of California in all respects except that the ventral sutures of the final whorl are raised.

Very similar specimens have been observed in the younger Talara shale formation in the La Brea-Pariñas area.

CIBICIDES NEWMANAE (Plummer)
Plate 6, figures 18–20

Discorbis newmanae PLUMMER, 1927, Texas Univ. Bull. 2644, p. 138, pl. 9, fig. 4.
Cibicides newmanae (Plummer) CUSHMAN & TODD, 1942, Cushman Lab. Foram. Research Contr., vol. 18, p. 46, pl. 8, fig. 16.

A single specimen from the Pale Greda formation agrees very well with the type from the Texas Midway formation.

CIBICIDES sp.
Plate 6, figures 21–23

A single, very small, typically planoconvex, conspicuously perforate specimen was found in the Pale Greda material. It is very probably an immature form.

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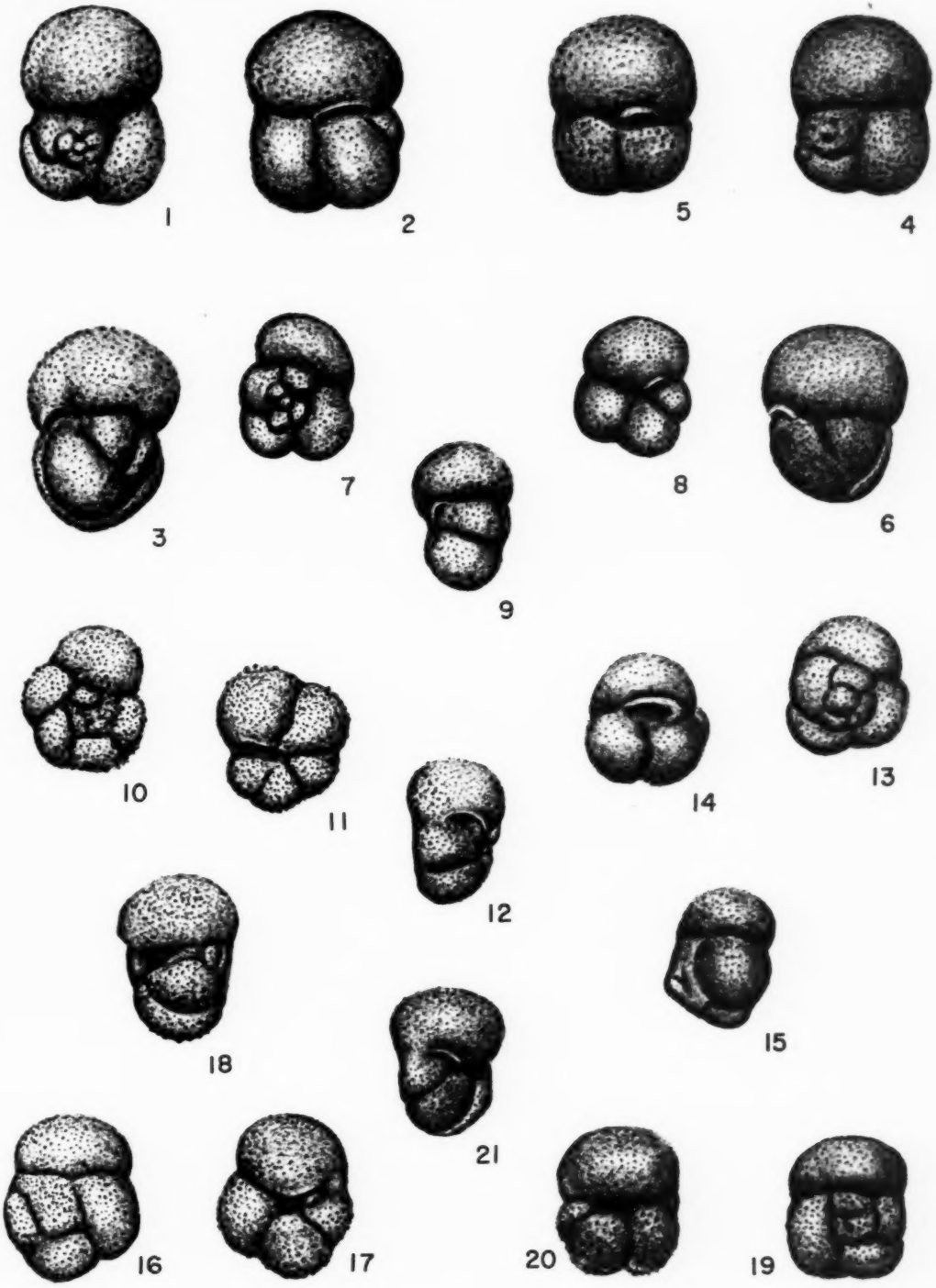
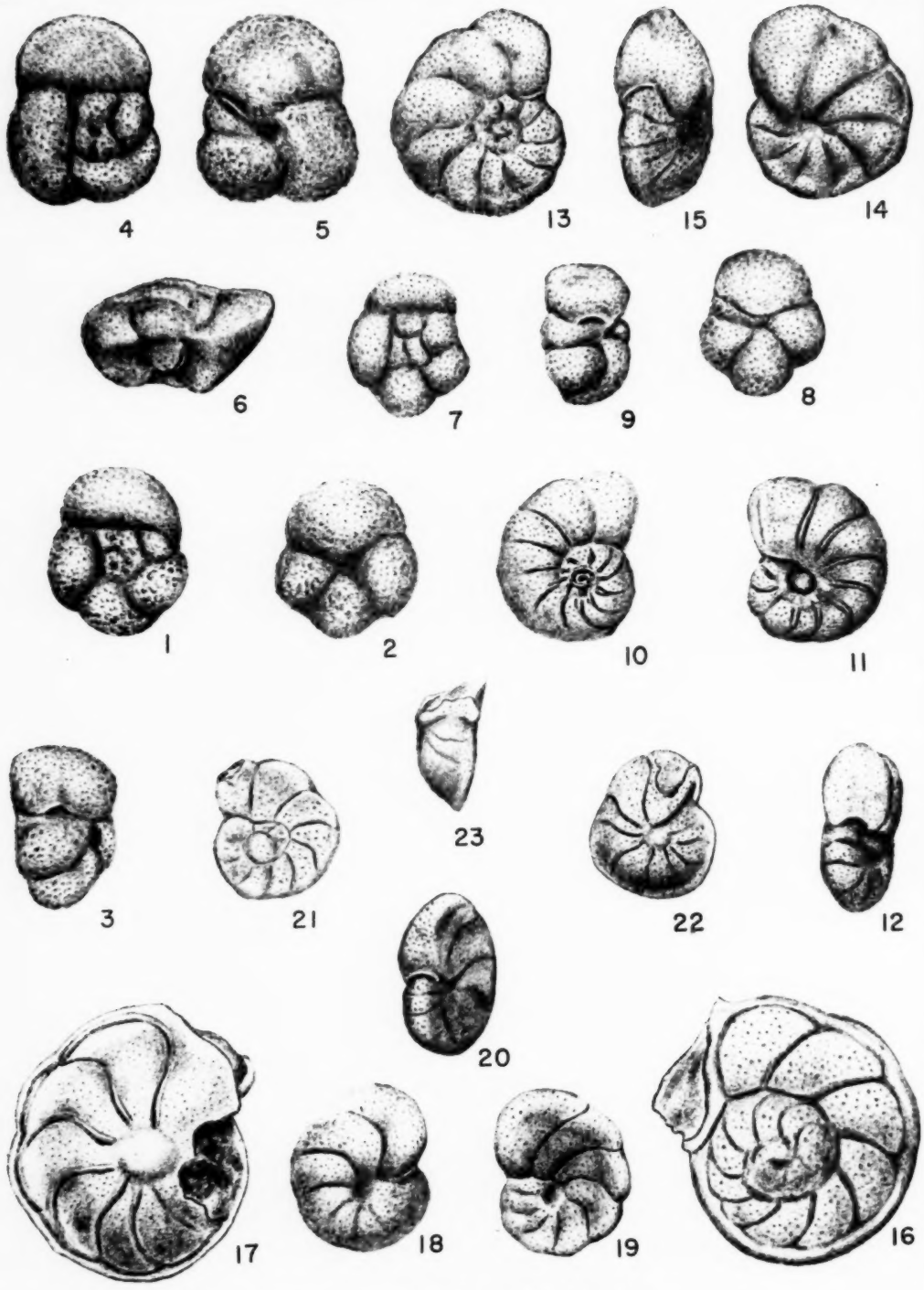
EXPLANATION OF PLATE 5

All figures ×85.

FIGS. *1–3—Globigerina pseudotriloba* White. I.P.Co. well 3422, core depth 3241–3248′. (p. 18)
4–6—Globigerina eocaenica Terquem. I.P.Co. well 4200, core depth 7672–7688′. (p. 18)
7–9—Globigerina triloculinoides Plummer. I.P.Co. well 3422, core depth 3241–3248′. (p. 18)
10–12—Globigerina cf. *G. wilsoni* Cole. I.P.Co. well 3297, core depth 1561–1579′. (p. 18)
13–15—Globigerina cf. *G. trilocularis* d'Orbigny. I.P.Co. well 3387, core depth 1507–1542′. (p. 18)
16–21—Globigerina stonei Weiss, n. sp. I.P.Co. well 3297, core depth 1561–1579′. *16–18*, holotype; *19–21*, compressed paratype. (p. 18)



Weiss, Paleocene Foraminifera, Peru



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MANUSCRIPT RECEIVED NOVEMBER 3, 1953

EXPLANATION OF PLATE 6

All figures ×85.

FIGS. *1–3—Globorotalia whitei* Weiss, n. sp. Holotype. I.P.Co. well 4200, core depth 7672–7688′. (p. 18)
4–6—Globorotalia crassata (Cushman) var. *aequa* Cushman & Renz. I.P.Co. well 4430, core depth 5074–5083′. (p. 19)
7–9—Globorotalia wilcoxensis Cushman & Ponton. I.P.Co. well 3422, core depth 3241–3248′. (p. 19)
10–12—Anomalina welleri (Plummer). I.P.Co. well 3357, core depth 2708–2731′. (p. 19)
13–15—Cibicides coonensis (W. Berry). I.P.Co. well 3422, core depth 3162–3190′. (p. 19)
16, 17—Cibicides cf. *C. fortunatus* Martin. I.P.Co. well 3387, core depth 1507–1542′. (p. 19)
18–20—Cibicides newmanae (Plummer). I.P.Co. well 4430, core depth 5074–5083′. (p. 20)
21–23—Cibicides sp. J.P.Co. well 3422, core depth 3241–3248′. (p. 20)

JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 1, PP. 22–36, PLS. 7, 8, 3 TEXT-FIGS., JANUARY 1955

AN UPPER EOCENE FAUNA FROM THE SAGE CREEK AREA, BEAVERHEAD COUNTY, MONTANA[1]

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ABSTRACT—A vertebrate fauna of uppermost Eocene (?Duchesnean) age from the Sage Creek area, Beaverhead County, Montana, includes eight species referred to four genera and is closely similar to the fauna from Duchesnean beds of Badwater Creek, Wyoming. New forms described are *Schizotherioides parvus*, n. gen., n. sp., and *Desmatotherium kayi*, n. sp. Previous works on the stratigraphy of the Cook Ranch and Sage Creek formations and vertebrate fossils from the area are reviewed and new interpretations presented. The Sage Creek formation is redefined to include about 200 feet of higher breccias and tuffs at its type locality and in adjoining areas.

THE SAGE CREEK PROBLEM

EARLY in his explorations of the Sage Creek area of Beaverhead County, Mont., probably about 1895, Earl Douglass located some Tertiary beds "7 miles northeast of Lima" which he considered Eocene in age. The only four vertebrate fossils that he collected there were: a maxilla of *Heptodon?*, a *Hyrachyus* skull, a much-weathered *Metamynodon?* jaw and a *Hyrachyus* tooth. This collection seemed incongruous (Douglass, 1901), since the lower Eocene "*Heptodon*" was found above the *Hyrachyus* skull and the advanced amynodont, which seemed to be the Oligocene *Metamynodon*, below the *Hyrachyus* tooth. It was not until reexamination of the area in 1903 that the specimens were described and figured (Douglass, 1903). Douglass did not attempt even at this time to resolve the age difficulty or draw boundaries between the supposed Eocene and Oligocene strata represented. Matthew (in Osborn, 1909) reidentified the specimens as *Helaletes*, *Hyrachyus* and *Amynodon* without further collection from or examination of the beds, thus reducing the age to middle and late Eocene.

No further geologic work was published on the Eocene(?) of Beaverhead County until, in 1931, H. E. Wood's party visited the area in the hope of finding diagnostic fossils or information that would define the Eocene and Oligocene boundary. Wood did not, at that time, examine Douglass' Sage Creek type locality but examined briefly the Tertiary sediments exposed in badlands along the west side of the road, which runs north and south past the Cook Sheep Ranch. In a cliff just opposite the ranch, Wood collected a small fauna that he considered middle Oligocene. The age determination was based largely on the presence of jaws and teeth of *Paleolagus haydeni* (Wood, A. E., 1933, p. 134). The Tertiary exposures of which this cliff is a part were designated by H. E. Wood (1934, p. 254) as the Cook Ranch formation. The cliff opposite Cook Ranch is the type locality. Wood made no attempt to map the formation, and apparently applied the name Cook Ranch to all of the Tertiary sedimentary rocks in the immediate vicinity.

In 1931 Wood was still in doubt as to the exact area from which Douglass obtained his specimens, but in 1933 it was located and described (Wood, H. E., 1934, p. 255). This locality is about 8 miles northwest of Lima and about 3 miles northwest of the Cook Ranch type locality. Wood noted among the Tertiary rocks here a south-facing cliff the lower beds of which are greenish-gray sandstone overlain disconformably—and Wood believed unconformably—by buff-colored, tuffaceous deposits. The contact is marked by a breccia of the underlying sandstone cemented by the tuffs. Wood did not find any additional vertebrate fossils in these beds but on the assumption that Douglass' four specimens all came from the greenish beds, called these beds the Sage Creek formation and correlated the overlying buff-colored deposits with the Cook Ranch formation. He interpreted the unconformity as representing the time interval between the Uintan and middle Oligocene ages.

[1] Publication authorized by the Director, U. S. Geological Survey.

My interest in the problem was aroused after a field assistant of M. R. Klepper, of the U. S. Geological Survey, had found a *Pseudocynodictis* skull and a *Subhyracodon* jaw, both of Oligocene age, in tuffs along the Cook Ranch type locality. This had raised the question of how much of the stratigraphic section was Eocene and how much Oligocene. In 1950, M. R. Klepper, Bradley Meyers (also of the Geological Survey) and I visited the Cook Ranch type locality and found specimens of agriochoerids, creodonts and tapiroids in the badlands at the heads of Draw No. 2 and No. 3 (Fig. 1). Comparison of these with more complete specimens collected previously from the same locality by LeRoy Kay, of the Carnegie Museum, showed the fauna to be uppermost Eocene. The genera and even the species agree closely with forms collected from beds of uppermost Eocene (?Duchesnean) age along Badwater Creek, Natrona County, Wyoming.

Finding such a fauna raised many questions about the Sage Creek area and the study was therefore continued. In 1951, LeRoy Kay conducted my party over the Sage Creek area. In 1952, a more detailed examination, especially of the contact between the Sage Creek and Cook Ranch formations was undertaken with Robert DeMar as field assistant. The collections made at that time and in the summer of 1953, which include a representative fauna from the Cook Ranch type locality, are being studied and will be the subject of a later publication. The Eocene fauna, however, forms such important evidence as to the age of the Sage Creek and Cook Ranch formations, that it was felt a description of it would facilitate work of other parties mapping in the area.

THE SAGE CREEK TYPE LOCALITY

Tertiary exposures are widespread over roughly 7 square miles in the Sage Creek area (secs. 28 to 34, T. 12 S., R. 8 W). bounded to the east and to the south by the Sage Creek road. The country is much dissected by numerous draws which run south and southwest into Sage Creek. The badlands which are carved out of the Tertiary deposits occur along the sides and at the heads of these draws where they form hills and cliffs of white to buff tuffaceous rock similar in appearance and composition to Oligocene deposits elsewhere in Montana.

The Sage Creek type locality is in the western part of these exposures, sec. 29, T. 12 S., R. 8 W. where they form an extensive badland area, the higher cliffs of which rise 200 to 250 feet above the floor of the draw. The principal exposure of the Sage Creek formation as defined by Wood and the hill from which Douglass obtained his fossils forms the north rim of a small amphitheatre of low cliffs southeast of the more striking exposures. Figure 2 is a map of the area.

The Sage Creek beds consist of evenly bedded tuffaceous sandstone light olive to yellowish grey in color, overlain disconformably, but apparently not unconformably by pinkish grey sandy tuffs that Wood identified as the Cook Ranch formation. The contact between the Sage Creek beds and the overlying deposits, best seen on the cliff which forms the north rim of the amphitheatre, is highly irregular and marked by a breccia of the sandstone cemented by the tuffs. The Sage Creek beds and the tuffs, which are here only a few feet thick, are much jointed and crossed by several minor faults. (The throw of the most pronounced of these is not more than 6 feet.) In addition to the calcified twigs, logs, and quartz and calcite geodes mentioned by Douglass the beds are traversed by lenses of aragonite which generally follow the bedding. The concretionary structures occur in strata both above and below the disconformity.

The Sage Creek beds have numerous lenses of coarser sandstone grading into a pebble conglomerate; a few narrow laminae of mudstone, and considerable cross bedding in patches. The strata above the breccia are more massively bedded and have a greater percentage of tuff. The conglomerate lenses are more numerous and the rock fragments composing them, quartzite cobbles and boulders with some volcanics, are of larger size. Both conglomerate and standstone lenses are cross laminated with high angles of inclination. In short, there is every evidence that the strata both above and below the disconformity are channel deposits with frequent changes in the type and rate of deposition.

The exposures of the Sage Creek formation are very limited. Traced eastward the greenish[1] sandstone disappears. No outcrop

which could be identified with any certainty as the Sage Creek formation was found in any of the draws to the north or east. Traced westward to a draw about ½ mile from the type locality, beds which are similar to and continuous with the Sage Creek beds are overlain conformably by the tuffs. There is no breccia. In the next draw greenish beds interfinger with pinkish gray tuffs. The contact with the underlying formation (?Beaverhead conglomerate) is covered. There is no absolute proof that the Sage Creek beds lense out. There is also no evidence that they are widespread and underlie younger sediments throughout any considerable portion of the area. Wood recognized the limited nature of the outcrops, but explained this by his interpretation of the Sage Creek formation as an erosional remnant. He considered the unconformity at the type locality a regional one representing a long time interval —Uintan to middle Oligocene. In the writer's opinion there is very little evidence for this.

The disconformity between the Sage Creek beds and the overlying tuffs is striking but channel deposits such as these may have local unconformities of marked relief because of the necessarily erratic distribution of the sediments. This is particularly true of deposits made by torrential streams in semi-arid climates. These unconformities may not represent any great time hiatus. The question as to how much time did elapse can only be answered by structural evidence from the beds, or, more precisely, by the fossils found in them. In this case, faults cross beds above and below the unconformity. Secondary deposition of minerals occurs in both. There is no marked lithologic difference. Most important, the fossil evidence does not bear out the age assignment of Uintan to the lower and middle Oligocene to the upper strata.

Compared to other localities in the area, the Sage Creek type locality is sparingly fossiliferous. The few fossils that have been found recently come from the beds above the disconformity. These are not diagnostic of middle Oligocene. No fossils have been found in the greenish beds, although intensive search has been made. Douglass' specimens therefore are the only criterion and there is good evidence from his published account that these came from above the disconformity.

Confusion as to this point is understandable, because Douglass' description both of the locality and the fossils is informal by modern standards. The only precise statement as to the level from which he obtained his specimens occurs in the description of the skull of one of them—where you would least expect it. The statement itself, however, is clear and indisputable. In the description of the jaw and skull doubtfully referred to *Hyrachyus*, he says (Douglass 1903, p. 156) "the specimen was in a breccia formed by the breaking up and recementing of the sandstone." There is only one breccia to which this description could apply and that is the one marking the unconformity. Since this specimen is also stated by Douglass to be from "a few feet below the *Heptodon*," it follows that the *Heptodon* maxillary fragment came from the buff colored beds above the unconformity. The *Heptodon* is the most clearly Eocene fossil from the locality. Therefore if any beds are determined as Eocene, it would be those above the unconformity, but these are the beds which Wood called middle Oligocene.

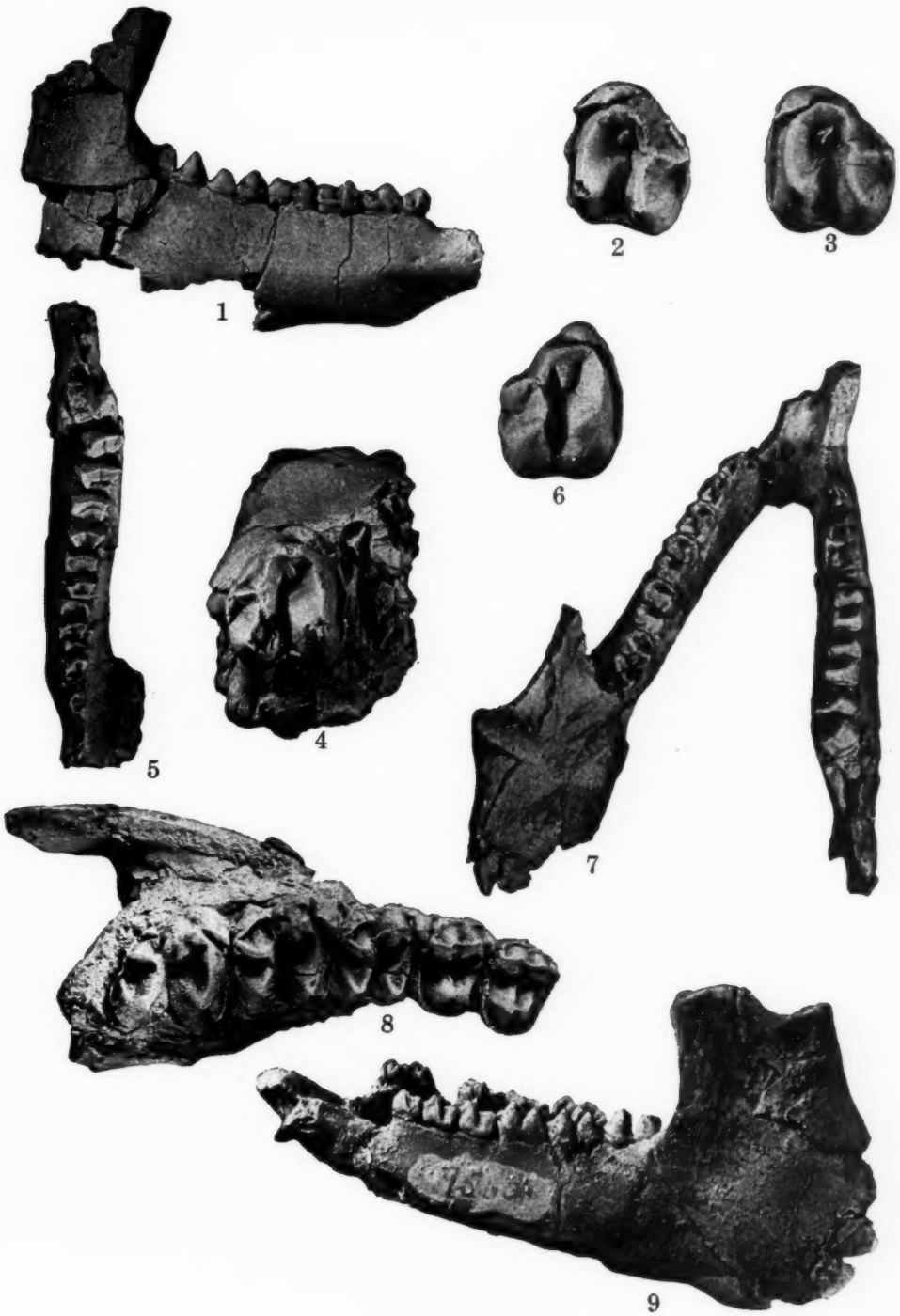
Moreover the upper Eocene fauna de-

[1] The terms "buff" and "greenish gray" have been used previously in describing these deposits. The equivalents in the National Research Council Color Chart are "grayish orange pink 10 R 8/2" and "pale yellowish brown 10 YR 6/2," respectively.

EXPLANATION OF PLATE 7

FIGS. *1–7, 9—Dilophodon leotanus* (Peterson). *1, 5*, lower jaw, lateral and crown views, USNM 20207, ×1; *2–4*, upper molars, USNM 20208, ×2; all Duchesnean beds, Badwater Creek, Wyo. *6*, M^3, YPM 1942-2, Hot Springs County, Wyo., ×2. *7, 9*, crown and lateral views of lower jaw, CM 9506, ×1, Sage Creek, Beaverhead County, Mont. (p. 29)

8—Desmatotherium kayi Hough, n. sp., holotype, maxilla P^3–M^3, CM 9561, ×1, Sage Creek, Mont. (p. 31)



Hough, Eocene mammals, Montana

Hough, Eocene mammals, Montana

scribed in this paper was obtained from pinkish gray tuffaceous beds lithologically similar to and continuous with those above the disconformity at the Sage Creek type locality. The greater number of specimens came from a draw just west of the Cook Ranch type locality. Correlation of the latter with the beds immediately above the unconformity at the Sage Creek type locality is therefore impossible because an Eocene fauna intervenes between the two.

TERTIARY SEDIMENTARY ROCKS IN THE DRAWS BETWEEN THE SAGE CREEK AND COOK RANCH TYPE LOCALITIES

The buff-colored beds that overlie the greenish sandstone at the Sage Creek type locality can be traced into all of the draws to the east where they form extensive badlands similar in lithology and topographic expression to those at the Sage Creek locality. The most prominent and fossiliferous of these are at the heads of Draw No. 2 and No. 3 (Fig. 1, b, c, and d). At localities c and d they form an amphitheatre of steeply sloping cliffs the sides of which are covered with a bentonitic clay, checked when dry, from which the harder more calcareous lenses of the bedrock protrude. Fragments weathering from bedrock are strewn down the slope and sometimes contain enclosed fossils.

West of this amphitheatre a few hundred feet south of locality X, a series of much dissected hills flanks the cliffs. At the base of these hills the upper lenses of conglomerate, particularly along the saddle that connects Draw No. 2 and Draw No. 3 at locality X, contain many mud balls from $\frac{1}{2}$ to 3 inches in diameter embedded in tuff. A conglomerate composed of small pellets forms a conspicuous band in the uppermost part of a small exposure near the mouth of the draw.

Buff-colored beds throughout the length of Draw No. 3 are underlain by a conglomerate with a base of medium-sized volcanic cobbles and huge pink rhyolite boulders. A very thorough search did not disclose anywhere in the draw the greenish sandstone that characterizes the so-called Sage Creek beds at the Cook Ranch type locality. All the fossils described came from various levels of the buff-colored beds with no ascertainable lithologic or structural dividing line. Various levels such as the conglomerate or the clay-pellet surface perhaps represent breaks in sedimentation, but these have no regular relationship with the occurrence of the fossils. There is every reason to suppose both from the fossil evidence and the nature of the sediments themselves that there was no long-continued break in deposition. The sediments are typical fluviatile deposits made in an arid or semiarid climate exposed, perhaps by a shift in the stream channel, to desiccation and later buried under a new layer of sand, silt, and in this case ash, when sedimentation was resumed.

THE SAGE CREEK FORMATION

No new formation names are proposed in this paper because it is felt that the Tertiary strata in the entire area should be mapped before this is done. A clarification of the term Sage Creek formation, however, is needed. The Sage Creek beds are obviously those beds from which Douglass obtained his fossils, i.e. the pinkish gray, fossiliferous tuffs above the disconformity at the type locality. These beds are continuous with and faunally the same as those which yielded the upper Eocene fauna described in this paper. The age of the Sage Creek beds of Douglass is, therefore, uppermost Eocene, i.e., Duchesn-

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EXPLANATION OF PLATE 8

All figures natural size

FIG. *1*—*Schizotheriodes parvus* Hough, n. gen., n. sp., holotype, M^2, M^3, USNM 20205, Sage Creek, Mont. (p. 34)

2—*Dilophodon* sp. ("*?Heptodon*" of Douglass), upper dentition P^4–M^3, Sage Creek, Mont. (p. 31)

3, 7—*Protoreodon tardus* Peterson, crown and lateral views of lower jaws, USNM 19116 and 19117, Sage Creek, Mont. (p. 35)

4–6, 9—*Desmatotherium kayi* Hough, n. sp. *4*, M^2, USNM 20203; *5*, M^3, USNM 20199; both from Sage Creek area, Mont. *6*, P^3, P^4, USNM 20202; *9*, M^1–M^3, USNM 20200; both from Duchesnean beds, Badwater Creek, Wyo. (p. 31)

8—*Mesagriochoerus* cf. *M. primus* Peterson, ventral view of skull, CM 9827, Sage Creek, Mont. (p. 35)

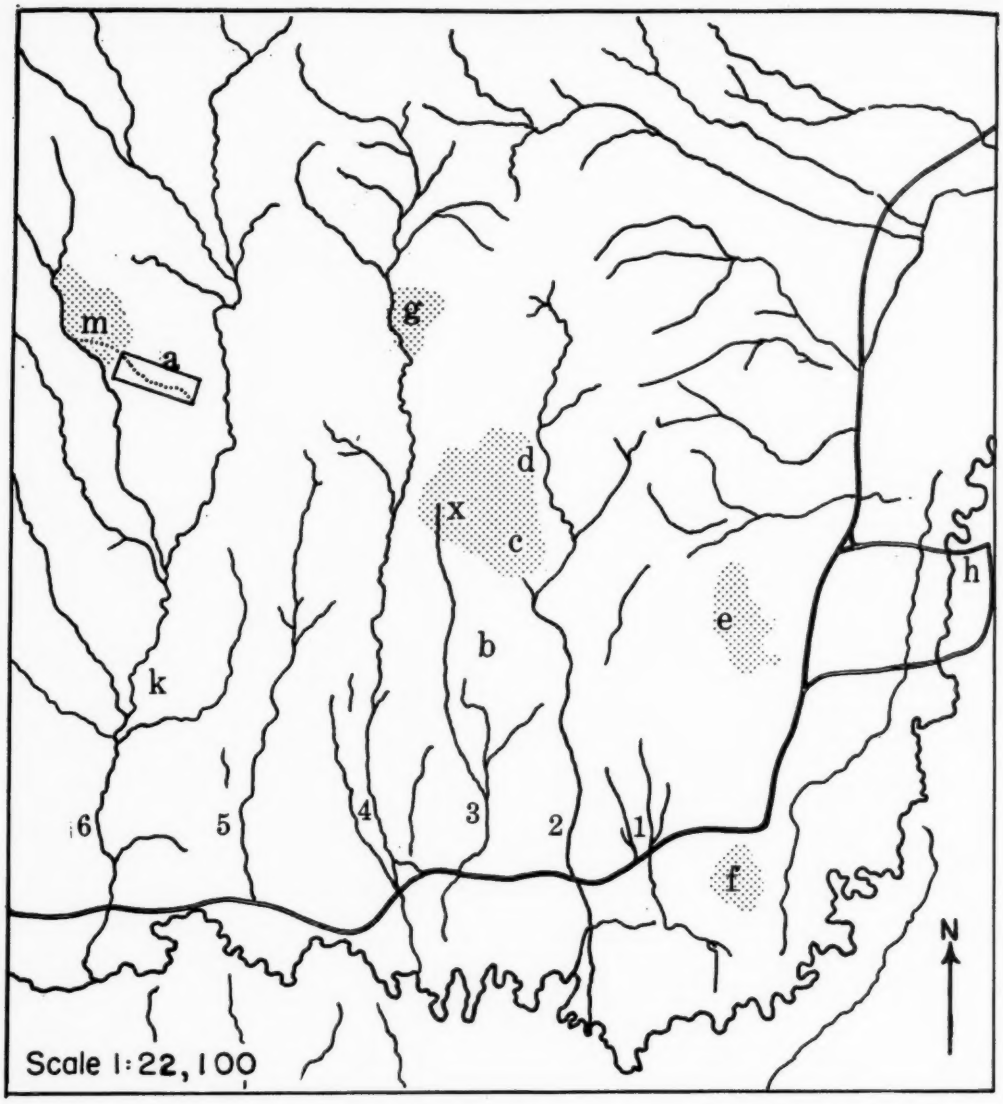

FIG. 1—Map drawn from aerial photograph of Sage Creek area, secs. 27–34, T. 12 N., R. 8 W. 1–5, draws leading into Sage Creek; a, Sage Creek type locality, rectangle indicates area included in map, text-figure 2, dotted line indicates position of disconformity; b, site of mud-pebble conglomerate; c, d, main upper Eocene fossil localities; e, Cook Ranch type locality; f, g, Oligocene fossil localities; h, Cook sheep ranch; k, ¼ sec. marker, 32–33; x, low hills of tuffaceous sand and clay containing mud balls; m, Oligocene fossil locality.

ean as that term is at present understood. They may include the greenish gray sandstone below the unconformity at the Sage Creek type locality but cannot be limited to that sandstone if the term is used in the way Douglass used it. They also include a part of Wood's Cook Ranch formation. It would seem to the writer, therefore, better usage to drop the term Cook Ranch formation and call all the Tertiary rocks below the post-Oligocene conglomerate and above the Beaverhead formation in the Sage Creek

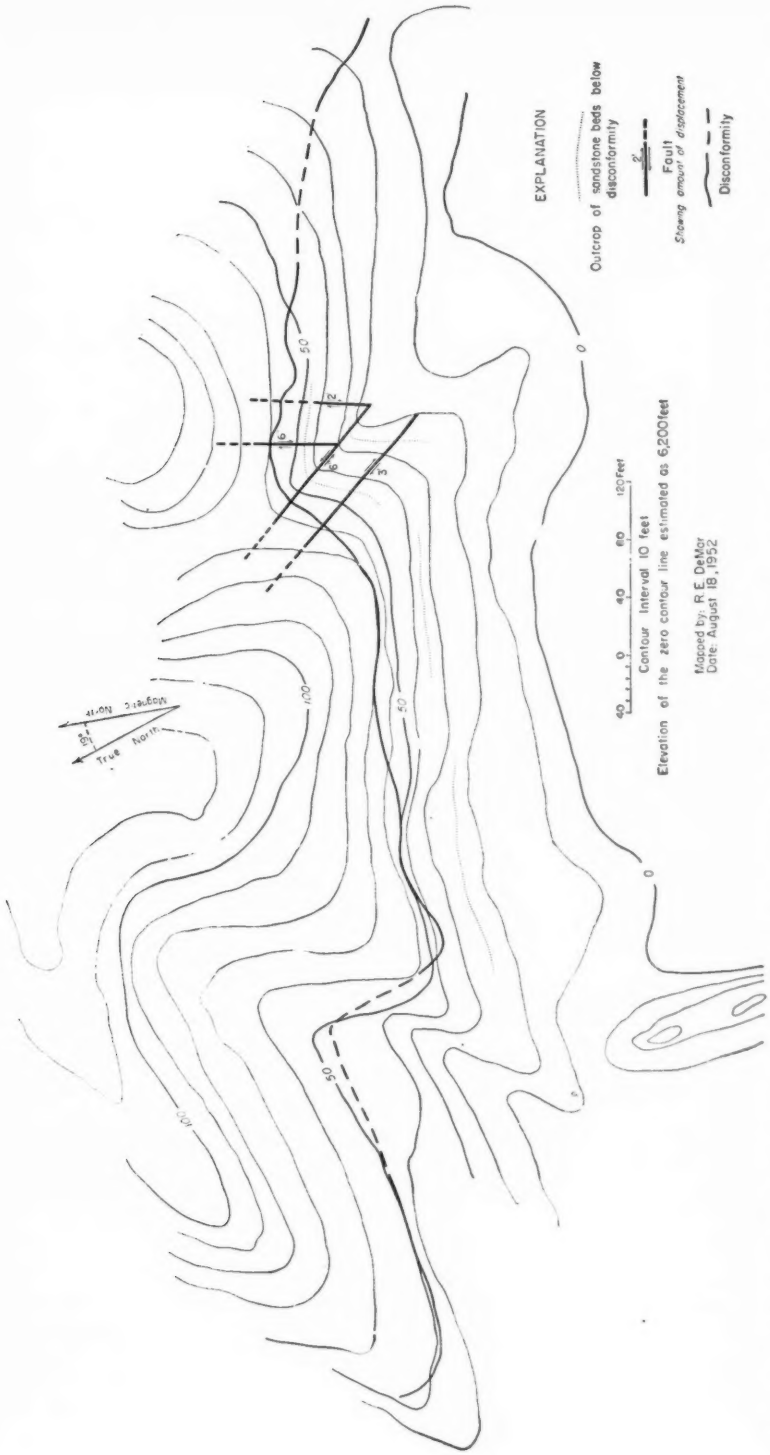

FIG. 2—Map of the Sage Creek type locality showing the outcrop of the light olive ("greenish") sandstone beds of the Sage Creek formation and the disconformity separating the Sage Creek from the overlying pinkish gray, sandy tuffs of the Cook Ranch formation. The strata dip about 5 degrees S, strike N 70° W. Douglass' fossils probably came from the beds above the disconformity.

area the Sage Creek formation, with upper Eocene and Oligocene stages. These relationships are expressed diagrammatically in Figure 2.

Whether the upper Eocene and Oligocene stages of the Sage Creek formation as here defined can be separated as members remains to be seen after more work in the area. Wood described a small group of specimens from the Cook Ranch type locality which he considered middle Oligocene in age. The writer and field assistant Robert DeMar collected a similar fauna the summer of 1953. Specimens collected from other localities in the area appear to be lower Oligocene. No dividing line has been located. It is questionable whether the Oligocene of Montana can be divided in any way conformable with the White River formation of the Great Plains. Evidence in the Sage Creek area at any rate suggests that sedimentation was continuous from at least Uintan to middle Oligocene, and perhaps later.

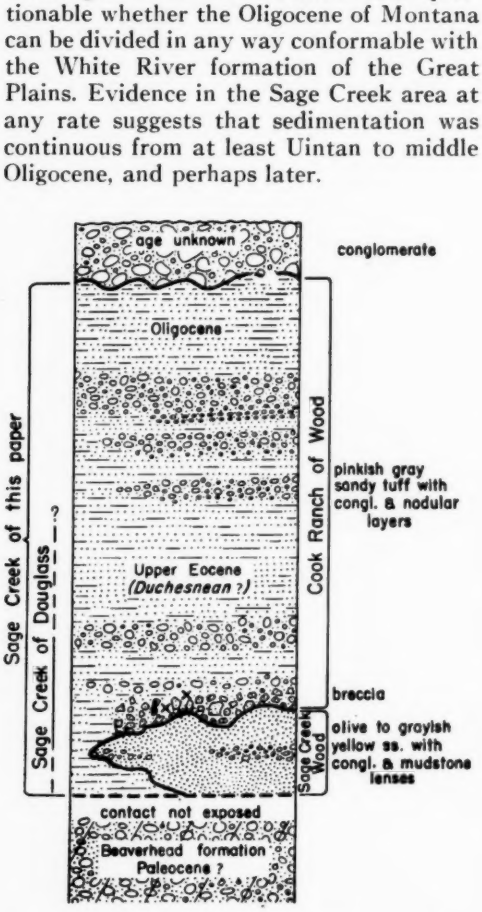

FIG. 3—Schematic section showing relationship of Cook Ranch and Sage Creek formations as described by Douglass, Wood, and Hough. x=approximate levels of Douglass' specimens.

COMPARISON OF THE SAGE CREEK FAUNA WITH THAT OF BADWATER, WYOMING, AND THE DUCHESNE RIVER FORMATION

The Sage Creek fauna is a scanty one both as to numbers of individuals and genera represented. It is composed almost entirely of tapiroids, agriochoerids, and protoreodonts. The generic and specific similarity to those from the Duchesne River beds of the Uinta Basin, and the Duchesnean deposits along Badwater Creek, Wyo., is so close, however, that the age equivalency of the faunas is unquestionable. The similarity of the Sage Creek specimens with those from Badwater Creek area is particularly notable, as will be seen from Table 1.

The Sage Creek and Badwater faunas differ most from that of the Duchesne River formation in the abundance and variety of

TABLE 1.—COMPARISON OF SAGE CREEK, BADWATER AND DUCHESNE RIVER FAUNAS

	Sage Creek	Bad-water	Duchesne River
Protictops alticuspis			x (3)
Hessolestes ultimus			x (3)
Hyaenodon sp.			x (3)
Pleurocyon sp.			x
Eosictis avinoff			x (2)
Leptotomus kayi	x		x (1)
Helohyus sp.			x (1)
Pentacemylus progressus			x (1)
Poambromylus kayi			x (3)
Teleodus uintensis			x (3)
Protoreodon tardus	x	x	x (3)
Hypertragulid	x	x	x
**Epihippus*	x	x	x (2)
Hyracodon			x (3)
**Dilophodon*	x	x	x (1)
Hyopsodus		x	
Agricochoerus cf. *A. minimus*	x	x	
Mesagriochoerus primus	x	x	x (1)
Diplobunops crassus	x	x	x (1)
**Desmatotherium*	x	x	
?Leptomeryx	x	x	x
Heteraletes=Dilophodon leotanus	x	x	x (1)
Megalamynodon	x		x (1)

(1) Randlett, (2) Halfway, (3) Lapoint—horizons of Duchesne River formation.

* Faunal lists from Badwater record *Mesohippus* sp., *Heptodon* sp., *Colodon* sp. These identifications are almost certainly incorrect—the respective genera are those given in the table.

the tapiroids and in the absence of *Teleodus*. These differences may be regional, due to differences in facies or, because all of the faunas are so scanty, merely accidents of collecting.

An examination of the levels from which the Duchesne River specimens were collected offers another suggestion. Kay (1934) divided the Duchesne River formation into three zones, Randlett (1), Halfway (2), and Lapoint (3). These zones were based on lithology; nevertheless as Scott (1945) states there is also a difference in faunas, the fossils from the basal Randlett being entirely different from those near the top of the Lapoint. Comparison of genera from the Duchesne River with genera from Sage Creek and Badwater show that those common to the three localities occur in the lowest level of the Duchesne River, i.e., the Randlett. Such White River genera as *Hyaenodon*, *Hyracodon*, *Teleodus* coming from the highest, i.e., the Lapoint horizon, are absent from the Badwater and Sage Creek faunas. The tapiroids, especially *Dilophodon* (*Heteraletes*) which is the most typically Eocene, are common to all of the localities and come from the lowest horizon of the Duchesne River. Granting that the rarity of fossils in all of the localities discussed makes any interpretation tentative, it is the writer's opinion that the beds in the Sage Creek area described in this paper and the beds along Badwater Creek which have been mapped as Duchesnean (Tourtelot, 1946) are time equivalents of the lowermost Duchesne River beds of the Uinta Basin, and upper Eocene in age. The question arises in fact, whether "Duchesnean" is a valid time unit. The more our knowledge of early Chadronian faunas increases the more apparent the similarity with those from the upper levels of the so-called Duchesnean. It is beyond the scope of this paper to discuss this problem fully; but evidence is accumulating from the work of the writer and others (Franklin Van Houten, John Clark, personal communication from manuscripts in preparation) that the time interval between the upper Uintan and lower Chadronian was very much less than the present time scale recognizes, and that faunal differences due to geographic distribution of species, changes of sedimentary facies and mere accidents of collecting have been misinterpreted as age distinctions.

SYSTEMATIC DESCRIPTIONS

Although this account is not intended as a revision of the genera included, the generic types and referred specimens other than those in this fauna are discussed, in many instances, because of the obscurity or ambiguity of the original description.

Order PERISSODACTYLA
Family HELALETIDAE
Genus DILOPHODON Scott, 1883

Dilophodon SCOTT, 1883, E. M. Mus. of Geol. and Arch., Princeton College, no. 3, part 4, pp. 51–52.

Type species.—*Dilophodon minusculus* Scott. The species holotype is the right ramus of a lower jaw with entire molar series and symphysis but lacking canines and incisors; Waskakie Basin, Bridger Eocene.

Author's definition of genus.—Lophiodonts closely allied to *Hyrachyus* having last lower molar with two transverse crests and a diastema between canines and molar series but with only three premolars in lower jaw.

DILOPHODON LEOTANUS (Peterson)
Plate 7, figures 1–7, 9

Heteraletes leotanus PETERSON, 1931, Annals Carnegie Mus., vol. 21, no. 68. pp. 68–69.

Holotype.—CM 11849, pair of lower jaws in an adolescent stage.

Locality.—Three miles north of Leota Ranch and a mile west of Green River, Uinta County, Utah.

Horizon.—Duchesne River, near base of series.

Referred specimens.—CM 9560, north face of ridge ½ mile west of Cook Ranch type locality, Beaverhead County, Mont.; USNM 20207, south side of Badwater Creek, 2 miles southeast of mouth of Clear Creek, Natrona County, Wyo.; USNM 20208, upper molar teeth from same locality.

Discussion.—Peterson distinguished *Heteraletes* from *Dilophodon* on the basis of the smaller size and the complete molarization of P_4. The type, however, as was first pointed out by G. E. Lewis to C. L. Gazin, is an immature jaw, consequently the small size is due to immaturity and P_4 is DP_4. The

specimens here referred to the species are mature individuals. They show no differences of generic rank either in size or character of the premolars from *Dilophodon*. In fact, they are barely separable specifically from *D. minusculus* on the basis of the lower jaw. Peterson's species is retained, however, because of the difference in age and locality and the fact that upper dentition is not certainly known, although some upper molars from the same localities as the lower jaws are here referred to the species. When more complete specimens are found, probably good specific characters can be described.

Revised diagnosis.—Lower jaw and dentition. Jaw short, very deep posteriorly, tapering rapidly anteriorly. Symphysis long and spout shaped, with the posterior margin opposite the posterior margin of P_3. P_1 absent; P_2 separated from the canine by a very short diastema. P_2 a small two-rooted tooth with protocone median in position, bounded anteriorly by an oblique crest from protocone to posterior margin of the tooth. P_3 with anterior cingulum, complete anterior cross crest, posterior fossa extending the transverse length of the tooth and bounded posteriorly by the raised posterior rim of the tooth, which thus forms an incipient posterior cross crest. P_4 more molariform but with the posterior crest lower than the anterior and, since there is no posterior cingulum, still representing the posterior margin. A well-developed anterior cingulum is present. M_1 with lophiodont tooth characters fully established, anterior and posterior cross crests complete and of almost equal height. Both anterior and posterior cingula are present. M_1 is much the smallest of the molar series nearer P_4 in size than M_2. M_2 is essentially like M_1 but the crests are higher and separated by a deep, narrow cleft. M_3 is much the largest of the series, almost twice the antero-posterior length of P_4 with extremely high, sharp crests. The anterior cingulum is well developed, but there is only the barest trace of a posterior cingulum.

Upper dentition—referred specimen USNM 20208, upper molar teeth. No upper dentition has been described for either *Dilophodon* or *Heteraletes*. A number of small tapiroid teeth found at both Badwater and Sage Creek at the same locality as, but not clearly associated with the lower jaws, seem to belong to this genus. The teeth, which consist of right M^2 and M^3 and left M^2 and M^3 (not from the same individuals), are the correct size for association with *Dilophodon*, do not fit in with any known genus, and have the configuration of M^3 expected in conjunction with the character of the last lower molar in *Dilophodon*.

The shape of these teeth is very characteristic and clearly distinct from *Helaletes boöps*. M^3 has a rounded triangular outline with an exceptionally large rounded parastyle forming the apex of the triangle, i.e., the anterio-external corner of the tooth. The paracone that is situated very close to the parastyle is also rounded, smaller than the parastyle and no more elevated. The metacone is much flattened and pushed in to form the postero-external side of the triangle. Both of the cross crests are very low where they join the paracone and metacone —both also low—rising internally to form high rounded cusps. The posterior crest is very short. The ectoloph is also extremely short with almost no posterior extension beyond the metacone. There is a marked anterior cingulum and postero-external cingulum. M^2 is similar to M^3, but with all of the features less pronounced.

These teeth are not at all like those of *Helaletes boöps*. In the rounded aspect of the molar, shape of the parastyle and paracone, pushed-in metacone, and short extension of the ectoloph posteriorly they resemble *Helaletes nanus*, which could be as Scott suggested a species of *Dilophodon*. The last upper molar, M^3 in *H. nanus*, however, is almost quadrate, and the ectoloph while short is nevertheless more extended beyond the metacone than in the specimens here described. This development, or lack of it, of the ectoloph in the upper last molar corresponds with the development, or lack of it, of the heel in the last lower molar. In *H. nanus* there is a heel, but no additional loph to M^3 while in *Helaletes boöps* there is a distinct loph. In *Dilophodon* the last lower molar has two lophs and only the barest suggestion of a heel which suggests strongly that the upper last molar would have a truncated ectoloph.

DILOPHODON sp.

Referred specimen.—*?Heptodon* of Douglass, CM 717, Sage Creek type locality a few feet above the breccia formed by the breaking up and recementing of the sandstone.

Discussion.—Identification of this specimen, which is a maxillary fragment with P^4-M^3, has been the subject of some controversy. Douglass referred it doubtfully to *Heptodon*. Matthew revised the identification, referring the specimen to *Helaletes*. Wood confirmed this, stating that it was inseparable from *Helaletes boöps*. Of these identifications, Douglass' was, in the writer's opinion, most nearly correct. Although the specimen is not the lower Eocene *Heptodon*, it certainly is not *Helaletes boöps*, and in many features more nearly resembles *Heptodon* than *Helaletes*.

The general shape of M^3, as will be seen from the figures, is like that of the M^3 referred above to *Dilophodon leotanus*. The parastyle and paracone have the same rounded appearance; the pushed-in and flattened metacone are closely similar. The internal cusps are elevated in the same manner, and the cross crests shortened. The ectoloph is truncated practically at the metacone and appears on the posterior surface of the tooth only as a slight thickening, barely separated from the posterior external cusp. The aspect of the tooth is thus as different as possible—within the limits of variation of these small tapiroids—from that of *H. boöps*. It is, in fact, at the opposite extreme, with *H. nanus* intermediate between the two. The pattern of P^4 and M^1 is almost obliterated in Douglass' specimen and M^2 in an advanced state of wear. As nearly as can be seen, however, these teeth also show differences from *H. boöps*. The cross crests of M_1 and M^2 are oblique, parallel and uncurved. P^1 seems to have had two internal cusps. These differences are clear enough for separation from *H. boöps*. The size of the teeth is somewhat greater than *H. nanus*, and considerably larger than the teeth referred in this paper to *D. leotanus*. The specimen is so fragmentary, however, that it does not seem desirable to describe a new species until more complete material is obtained.

Genus DESMATOTHERIUM Scott, 1883

Desmatotherium SCOTT, 1883, E. M. Mus. of Geol. and Arch. Princeton College, No. 3, Part 4, pp. 51–52.

Type species.—*Desmatotherium guyotti* Scott. The holotype of this species is a portion of palate with complete right upper dentition, lacking only the incisors; Waskakie Basin, Wyo., Bridger Eocene.

Author's definition of genus.—Lophiodonts, closely allied to *Hyrachyus*, having the molar teeth constructed exactly as in that genus but differing from it in the pattern of the third and fourth premolars, which have two internal cusps instead of one. There is a long diastema between the canine and first premolar. Dental formula I ? ? C 1–1 Pm. 4–4, M 3–3.

Revised diagnosis.—Scott was primarily concerned in differentiating *Desmatotherium* from *Hyrachyus*. For the purposes of this paper it is more importnat to differentiate *Desmatotherium* from *Colodon*, which it much more strongly resembles. The most important distinction seems to lie in the size and shape of the canine (if the tooth figured by Scott with the type is correctly associated). It also differs in the somewhat smaller size of the cheek teeth, the relatively greater antero-posterior diameter of the premolars, especially P^4, and the relatively smaller size of the premolars relative to the molars.

DESMATOTHERIUM KAYI Hough, n. sp.
Plate 7, figure 8; plate 8, figures 4–6, 9

Holotype.—CM 9561. Portion of maxilla including P^3–M^3 and root of zygoma.

Locality.—Sage Creek area, near top of west side of ridge ½ mile west of Cook Ranch type locality, Beaverhead Co., Mont.

Horizon.—Duchesnean Eocene.

Referred specimens.—USNM 20200, maxilla with M^1-M^3; USNM 20201, upper molars P^3–M^1; USNM 20204, M^2—all from the south side of Badwater Creek, Wyo.; USNM 20203 M^3; USNM 20199 M^3;—both from the Sage Creek area, Mont., same locality as the type; CM 8930, immature lower jaw from the Sage Creek type locality above the breccia marking the disconformity; CM 12088, mature lower jaw, same locality as the type.

Diagnosis.—Upper dentition. Anteroposterior diameters of the premolars narrower than in *D. guyotti*. Size progression from P^3 to M^3 greater. Ectoloph of M^3 shorter, parastyle larger, paracone higher and sharper.

Lower dentition. The lower jaw of *Desmatotherium guyotti* is unknown. Several lower jaws in this collection fall into the proper size range and in other respects seem to belong to the genus. The molars are virtually indistinguishable from those of *Colodon*. The premolars differ in being narrower transversely with P_3 and P_4 more molariform.

Discussion.—In the proportions of the premolar and molar dentition *D. kayi* is intermediate between *D. guyotti* and *Colodon occidentalis* (Table 2). It is a question, therefore, into which genus the species falls, but from the very incomplete material on hand the Sage Creek species seems nearer *Desmatotherium*. The specimens of *Desmatotherium* are in all cases so incomplete that the real relationship between that genus and *Colodon* is uncertain. The two seem to represent a continuous line of descent from Bridgerian to Orellan time.

Subfamily RHINOCEROTOIDEA
Family AMYNODONTIDAE
Genus AMYNODONTOPSIS
AMYNODONTOPSIS cf. A. BODEI Stock

Holotype.—Skull with cheek-tooth series P^3-M^3, CIT 1087.

Locality.—Sespe, north of Simi Valley.

Horizon.—Sespe, upper Eocene (Duchesnean).

Generic and specific characters.—Larger than *Amynodon antiguus, A. advenus* or *A. erectus;* less robust than *Amynodon intermedius*. Nasals short, with anterior ends situated considerably behind level of anterior ends of premaxillaries. Facial fossae extend well backward and form deep recesses that extend to the inner sides of and behind the anterior orbital rim. Dentition /3 1 3 1. Length of molar series relative to length of cheek tooth series P^3-M^2 greater than in *Amynodon*. Referred specimen: weathered lower jaw, CM 794, collected by Earl Douglass from Sage Creek type locality, Beaverhead Co., Mont., in 1897.

Discussion.—The Sage Creek specimen referred to this genus is a poorly preserved lower jaw with all of the teeth missing except a portion of M_1 and the root of the right canine. The molar alveoli are so broken as to form a gap in the jaw bone. A few measurements can be made, however, with reasonable accuracy, and Douglass' description and measurements agree essentially with results obtained by the writer.

Douglass thought the jaw that of an advanced amynodont, close to *Metamynodon*. Matthew referred it to *Amynodon intermedius*. Wood in his main discussion of Douglass' specimens (Wood, 1934, p. 242) considered it advanced over any species of *Amynodon*, but closer to *A. intermedius*. He suggests comparison with *Megalamynodon* of the Duchesne River, Utah, but does not

TABLE 2.—COMPARISON OF *Desmatotherium* AND *Colodon*
Measurements of upper dentition in mm.

	D. guyotii PM type	*Desmatotherium kayi*						*Colodon occidentalis*	*Colodon dakotensis*
		CM 9561	USNM 20200	USNM 20202	USNM 20203	USNM 20199	USNM 20204		
Ant.-Post. P^3	11	10		9				10	11.5
Transverse P^3	13	13		12				15	17
Ant.-Post. P^4	12	10		9				10	12
Transverse P^4	14	14.4		12.3				16	18
Ant.-Post. M^1	13	12	11					13	15
Transverse M^1	16	15	14					17	18
Ant.-Post. M^2	15	15	12.5		13.6		12		17
Transverse M^2	16	16.5	14.5		15		14.5		20
Ant.-Post. M^3	17	16.2	14			15			17
Transverse M^3	17	17	15			17			20
Length P^3–M^3	63	61							
Length M^1–M^3	43	42	37						

make the comparison. Probably Stock's description of *Amynodontopsis* (Stock, 1933) was not available to him at the time of writing. At any rate Wood later reversed his original opinion and stated that after further study he considered the Sage Creek specimen *Amynodon advenus* (Wood, 1934, p. 255). The type of *Amynodon advenus* Marsh consists of two upper molars. Since Wood could not have compared these two upper molars with the Sage Creek lower jaw without teeth, he evidently means the paratype, YPM 11453, a skull and jaws on which Troxell based *Amynodon erectus*. This specimen was collected near White River, Utah, at the base of a zone on horizon c not far from the point where Douglass started his measurements of that zone (Kay 1934, p. 360). The specimen is therefore the upper Uinta, not the lower Uinta as Wood states.

This controversy over the identification of Douglass' specimen requires more discussion of amynodonts than is warranted by the actual importance of the poorly preserved lower jaw. Amynodont remains are rare; very few skulls and jaws have been described. Probably the best treatment is that of Stock (1933) already cited in which he not only describes the Sespe skull in considerable detail but discusses all of the known species of *Amynodon*, giving the molar ratios $(M1-M3\times100)/(P2-M3)$ for each. This ratio is significant because progressive enlargement of the molar dentition relative to the total cheek tooth length is a feature of the evolution of the amynodonts. Stock discusses only briefly the size and position of the canine but this too is significant.

The earliest amynodonts known are those small-sized specimens with small erect canines that are referred to *A. antiquus* (middle Eocene). The molar ratio is 65–67; the antero-posterior diameter of the canines approximately 15 mm. In the upper Uinta—there are no amynodonts known from the lower Uinta—this line is apparently continued in *A. erectus* Troxell. These, too, are small sized and have a molar ratio of 66.44 mm. The canines are relatively small, the lower canine in the type measuring approximately 18 mm.

Amynodon intermedius Osborn is also an upper Uintan species from about the same level as *A. erectus* Troxell. *A. intermedius* is a large specimen with large, probably semi-procumbent canines. Information and measurements furnished by Loren Toohey show the molar ratio to have been 68.56. The left canine is represented by the root, the right has been restored at an angle of 45 degrees. The writer agrees with Mr. Toohey that the angle is too great. The effect looks awkward. In all amynodonts the lower canines shear up and forward of the upper canines. If the lower canines had the procumbent position in which Osborn restored them, this type of occlusion would be impossible. (Troxell remarks on this in his discussion of the wear on the posterior side of the lower canine in *A. erectus*.)

Metamynodon, the culmination of the amynodont line in the lower Oligocene, is known by two described species, one *M. chadronensis* Wood, with a lower cheek-tooth length of 187 mm., the other *M. rex* Troxell with an upper cheek-tooth length of 202 mm. The molar ratio of *M. chadronnsis* compiled from the figures given by Wood (1937) is extraordinarily large, 78.47. Molar length relative to the total cheek-tooth length is greater than that of any specimen of *Metamynodon planifrons*. *M. rex* has a molar ratio of 69.40, which is more normal. The canine is unknown in *M. chadronensis*. In *M. rex* the diameter is 28.6 mm.

Megalamynodon of the Duchesne River formation in the Uinta Basin is a large form with a cheek-tooth length of 217 mm. The molar ratio, however, from the measurements by Scott (1945) is low, 67.29, and the canine is small, 24 mm. antero-posterior diameter.

Metamynodon planifrons, the largest of the amynodonts, has a total cheek-tooth length of from 212 mm. in the smaller specimens to 225 mm. in the larger. The molar ratio ranges from 70 to 75. The latter figure is from a lower jaw, AMNH 553. The canines are large, the antero-posterior diameter varying from 31 to 35. mm. The lower canine is usually the larger.

Amynodontopsis occurring in the Sespe beds, considered equivalent in age to the Duchesne River formation, is smaller than *Megalamynodon;* the cheek-tooth length is 160 mm. The molar ratio is 69.48. The canine is missing, but the alveolus measures

approximately 26 mm. in antero-posterior diameter.

The Sage Creek specimen, a lower jaw, and *Amynodontopsis*, a skull without jaws, are not strictly comparable. Nevertheless, the molar indices are sufficiently close to be suggestive. That of the Sage Creek specimen is 69.80. The cheek-tooth length, 149 mm., is somewhat less than that of *Amynodontopsis*, but the difference appears to be negligible, especially in view of the fact that the measurement of the Sage Creek specimen was made from alveoli. Douglass gives 28 mm. as the greatest length of the canine, but the writer believes this is too large. The alveolus is badly broken. The roots of amynodont canines are larger than the exposed portion and start forward and outward but make a sharp bend upward as they emerge from the alveolus. Therefore, the diameter differs according to the point at which the measurement was made. The writer believes 24 ± mm. comes nearer the probable antero-posterior diameter of the tooth as it leaves the alveolus. The measurements, therefore, come closer to those of *Amynodontopsis* than to those of any other described species. *Amynodon intermedius* is both larger and has larger canines, although these differences may not be significant. Stock suggests the possibility that *A. intermedius* which is close to *Amynodontopsis* in the size and shape of the facial fossae, as well as the relative dental proportions, should be referred to *Amynodontopsis*, and with this the writer agrees.

In any case the Sage Creek amynodont is not *A. erectus*. It is in fact a great deal nearer *Metamynodon*, as Douglass maintains.

Superfamily ?CHALICOTHERIODEA
Family ?CHALICOTHERIIDAE
Subfamily ?EOMOROPINAE
Genus SCHIZOTHERIODES Hough, n. gen.

Type species.—Schizotheriodes parvus Hough, n. sp.

Definition of genus.—M^2 and M^3 size of corresponding teeth of *Helaletes* but structure of them closely similar to those of *Eomoropus annectens* Peterson.

SCHIZOTHERIODES PARVUS Hough, n. sp.
Plate 8, figure 1

Holotype.—M^2 and M^3, USNM 2025.

Locality.—Sage Creek area, Draw No. 2, west of Cook Ranch type locality, Beaverhead Co., Montana.

Diagnosis and discussion.—Two molar teeth, M^2 and M^3, USNM 20205, in the Sage Creek collection from Draw No. 2—the same general locality and horizon as the *Desmatotherium* specimens—are unlike that genus, or any Helaletinae, and Hyrachyidae (National Museum collections), or as far as could be ascertained, any genus described in the literature. They resemble *Chasmotheriodes* sp. Wood (*Hyrachyus intermedius*) PM 10095 and may possibly be a smaller species of that genus than the one Wood described. The structure of the molars, particularly M^3, however, bears a striking resemblance to *Eomoropus annectens* Peterson CM 3109, although much smaller. This resemblance is seen especially in the height and prominence of the parastyle, which is much the most conspicuous element of the tooth. It forms a transversely elongated cone at the extreme antero-external corner of the tooth and is well separated from the paracone, which is so small and low as to appear almost a vertical ridge along the external face of the tooth rather than a definite cusp. The metacone is also inconspicuous and situated far posteriorly. The ectoloph forms a short but prominent ridge extending from the base of the parastyle to the base of the metacone and but little beyond it. The protoloph seems to be derived from the parastyle and does not touch the paracone. The metaloph is shorter than the protoloph because of the internal position of the metacone from which it starts. A cingulum surrounds the anterior, and antero-internal border of the crown of the tooth.

M^2 is similar in general characters to M^3, but the metacone and paracone are more prominent as they are in *Eomoropus annectens* and have about the same position they do in that species. The external face of both is depressed but that of the metacone considerably more internal in position. The parastyle is broken but was evidently prominent and loosely connected with the metacone.

The teeth are very nearly the size of *Helaletes* yet are clearly not related to that genus or, in the writer's opinion, to the lophiodonts. The true systematic position of the specimen will have to await more

complete material, and this description is merely given to facilitate comparison and to suggest the possibility of more numerous and varied chalicothere-like animals than are now known.

Order ARTIODACTYLA
Family AGRIOCHOERIDAE
Genus DIPLOBUNOPS Peterson

Diplobunops PETERSON, 1919, Ann. Carnegie Mus., vol. 12, no. 76.

Type species.—Diplobunops uintensis Peterson. The species holotype is a skull without a mandible, CM 2967; 1 mile south of Baser Bend of Green River, Utah; Randlett substage of Duchesne River (Eocene).

Discussion.—This genus is distinguished from *Mesagriochoerus* by the diastemata that isolate P^1 and the pronounced constriction of the muzzle just posterior of that tooth. Two species have been described, *D. uintensis* Peterson from the Uinta Eocene, and *D. crassus* from the Duchesnean of the Uinta Basin. The differences between the two are in the degree of development of the diastemata, protoconules on the upper molar, deuterocone of P^3 and of the proportions of the skull and cranium, both considerably broader in *D. crassus*. These specific differences may be valid but probably do not separate all of the Uinta specimens of *Diplobunops* from all of the Duchesnean. Both species are probably found in both horizons. In the Badwater collection two skulls, USNM 20303, 20304, have been identified by C. L. Gazin as *Diplobunops crassus* and *Diplobunops* cf. *D. crassus*, respectively.

No skulls in the Sage Creek collection belong to this genus but their absence is probably an accident of collecting. Several isolated molars and jaw fragments could be either *Diplobunops* or *Mesagriochoerus* since it is virtually impossible to separate the two genera on cheek teeth alone.

Genus MESAGRIOCHOERUS Peterson

Mesagriochoerus PETERSON, 1934, Annals Carnegie Mus., vol. 23, p. 377.

Type species.—Mesagriochoerus primus Peterson. The species holotype is a skull and lower jaw, CM 11893; 1 mile south of Baser Bend, Uinta County, Utah; Randlett substage of Duchesne River (Eocene).

Discussion.—The author's diagnosis is too long to repeat here. The principal distinction in the dentition of *Mesagriochoerus* from *Agriochoerus* is in the stage of molarization of P^4 and the absence of diastemata. In *Protagriochoerus* both the protocone and deuterocone are simple. In *Mesagriochoerus* the apex of the protocone is twinned with a ridge dividing the incipient tritocone thus formed from the protocone. *Agriochoerus minimus* Douglass shows a further advance with the external cone completely divided into protocone and tritocone. In the White River agriochoerids this division is carried still further and the deuterocone is also twinned.

MESAGRIOCHOERUS cf. M. PRIMUS Peterson
Plate 8, figure 8

Only one species of *Mesagriocherus* has been described. In the Badwater collection a skull and mandible minus the coronoid processes (USNM 20305) was identified by C. L. Gazin as *Mesagriochoerus* cf. M. *primus*.[1] A skull from Sage Creek (CM 9827) lacking the anterior part but with the roots of P^1 and the canine preserved on the left side appears to belong to this genus, rather than to *Diplobunops*.

Family MERYCODONTIDAE
Genus PROTOREODON Scott & Osborn

Protoreodon SCOTT & OSBORN, 1887, Amer. Phil. Soc., Proc., vol. 24, p. 257.

Type species.—Protoreodon parvus Scott and Osborn.

PROTOREODON TARDUS Peterson
Plate 8, figures 3, 7

Holotype.—CM 12040. Skull and lower jaw of a young individual; Beaver Divide, Wyoming, uppermost ? Duchesne River or lowermost Chadron.

Referred specimens:—CM 9559, a partial skull and mandible; USNM 19116 and 19117, two mandibles. Sage Creek area, Beaverhead County, Mont.

Discussion.—Protoreodon, which is distinguished from *Merycoidodon* primarily

[1] This specimen, USNM, 20305, is now identified by C. L. Gazin as *Protoreodon*. From recent studies he believes *Mesagriochoerus* to be indistinguishable from *Protoreodon*.

by the form of P^4 and the absence of an antorbital fossa, is, next to *Triplopus*, the most numerous of all Uinta mammals. It is not found in the Duchesne River beds of the Uinta Basin. *Protoreodon tardus* was described by Scott from specimens obtained from the supposed Duchesnean of the Beaver Divide, Wyoming. It is distinguished from the Uinta species by the presence of a shallow antorbital fossa, reduced size of the intermediate connules of the molar, and other minor skull differences that may or may not prove important in a restudy of the genus. In any case, protoreodons of a large species, probably *P. tardus*, are well represented in both the Sage Creek and Badwater collections.

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THREE NEW GENERA OF ALGAE FROM THE UPPER DEVONIAN OF NEW YORK

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ABSTRACT—*Drydenia foliata, Hungerfordia dichotoma* and *Enfieldia mutilata* (new genera and new species) are described as compression-impression remains of marine algae. The majority of the specimens come from the marine Ithaca and Enfield formations of Upper Devonian age. A few are younger. Comparison is made between the fossil and living algae mainly on the basis of gross morphology.

INTRODUCTION

THE literature on early Paleozoic fossils of New York abounds with reports of algae. Almost equally frequent are carefully considered warnings of the difficulty of proving that fossils are algae and of assigning them to taxonomic groups based on living algae (White, 1903; Ruedemann, 1925). Many of the supposed algal remains appear to be animal trails or burrows as for example some species of *Buthotrepis* (Reudemann, 1925). The same is probably true of *Arthrophycus alleghaniensis* recently reviewed by Becker and Don (1952). Their argument that the early Silurian is at best the dawn of our flora and that therefore this much disputed fossil is probably a primitive plant is of little consequence since *Arthrophycus* shows no definable plant characteristics whatsoever. The oldest authenticated vascular land flora now known is from Australia and it is Middle Silurian. It is a flora containing highly organized and complex forms. This should, however, encourage thinking in terms of a much older origin for vascular plants and there is every reason for continuing to seek for earlier indications of vascular land plants in Ordovician and Cambrian strata. The description by Kryshtofovich (1953) of an isolated plant described as a new genus of lycopods (*Aldanophyton antiquissimum*) from Middle Cambrian strata supports this contention. The investigations of Fenton and Fenton (1939) and others show the presence of complex algae in the Cambrian and Pre-Cambrian. Silurian and Devonian depositions therefore may, in fact do, contain primitive plants but only as they coexist with more highly envolved forms. Recent summaries of the status of many early fossil algae are those of Fenton (1946), Johnson (1946, 1951) and Elias (1946).

A sketch of some of the most widely accepted genera of fossil algae from the early Paleozoic of New York will indicate the groups that existed and serve as background for the new genera to be described. The well known genus *Cryptozoon* appears in the Cambrian (Goldring, 1938). It is often placed in the Spongiostroma among the Cyanophyta. Fenton (1946) however is inclined to regard such forms as predominantly Rhodophyta.

From the Ordovician Ruedemann (1925, 1926) has described *Delesserella salicifolia*, a leaf-like, supposed red alga from the upper Utica shale, which resembles closely the living genus *Delesseria* of the Rhodophyta. Among others Pia (Hirmer, 1927) has accepted the authenticity of this species. The red algal family Solenoporaceae is represented by *Solenopora compacta* var. *trentonensis* (Ruedemann, 1909). Two other Ordovician forms that have gained wide acceptance are *Primocorallina* Whitfield, 1894, and *Callithamnopsis* Whitfield, 1894, restudied by Ruedemann (1909). They are interpreted as belonging to the family Dasycladaceae of the Chlorophyta, a family with probably the best known fossil record among the algae. The genus *Corematocladus* Ruedemann, 1909, is accepted by some as an alga but usually classified as incertae sedis (Hirmer, 1927). The genus *Sphenophycus* Ruedemann, 1912, is considered by

[1] Published by permission of the Deputy Minister, Department of Mines and Technical Surveys, Ottawa, Canada.

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certain authors (Hirmer, 1927) as incertae sedis but Fenton (1946) regards it as a possible member of the Phaeophyta close to *Postelsia*.

The most striking Devonian algae from the standpoint of resemblance to modern forms are microfossils described from Onondaga chert (Baschnagel, 1942). Chlorophyta, Pyrrophyta and Cyanophyta are represented in the collection. Perhaps the most interesting feature of this discovery is the presence of filamentous green algae related to those forms from which some morphologists believe vascular plants may have arisen. M.C. White (1862) published a brief note on these microfossils but they have been neglected until recently. It is believed that the continued investigation of this and similar chert deposits may yield evidence of some phylogenetic value in algal studies.

Of the various larger, frondose structures often referred to as Devonian fucoids, *Thamnocladus* White, 1903, is the most commonly accepted. White described *T. clarkei* from the Chemung, Hollick (1910) added *T. passifrons* from Catskill beds and Kräusel and Weyland (1934) described *T. buddei* from the Middle Devonian of Germany. The genus *Haliserites* Sternberg, 1833, used by many workers for some Devonian algae, was founded on one poorly preserved Cretaceous specimen and probably should never have been applied to these older plants. White (1903) erected the genus *Taeniocrada* for a number of specimens previously referred to *Haliserites* and in which he found vascular tissue. Undoubtedly a number of specimens labeled *Haliserites* could be placed in White's genus which is now a well known member of the Psilophytales (cf. Stockmans, 1940). Possibly some of the non-vascular specimens of *Haliserites* can be included in *Thamnocladus* as Hollick indicated (1910). *Prototaxites* Dawson, 1859, is found in both Silurian and Devonian deposits as a petrified axis. Some New York collections were described by Penhallow (1893) as *Nematophytum crassum*. The plant is regarded as a member of Phaeophyta: incertae sedis by Pia (Himer, 1927) who also notes its resemblance to the family Codiaceae of the Chlorophyta. On the other hand Lang (1937) relates it to a group of supposed land plants, the Nematophytales, whose evolutionary position may be on a level with vascular cryptogams despite its lack of vascular tissue. Høeg (1942) supports this interpretation and develops evidence that *Prototaxites* either grew terrestrially or that its habitat was subaerial. The majority of other named "algae" remain in the category of doubtful fossils and can be omitted here.

It is thus clear that by, or long before, Devonian time there existed representatives of several phyla of algae whose close relationship to modern forms is not doubted. It is also true that the vast Devonian deltaic strata of central New York which were deposited under marine conditions have so far yielded relatively few algae. They have been much richer in fossil land plants, ones which floated out into the open sea, sank and were preserved. Hence it is of particular interest to record and describe some additional algal forms which may have lived in the marine environment. The collection of these specimens by Dr. L. C. Petry, Dr. Pearl Sheldon, Dr. John W. Wells, and others has been growing at Cornell for a considerable period of years. Until a few years ago all of the numerous specimens from the Ithaca region had come from one horizon, the younger Enfield formation. At that time Dr. Robert Ross, now of Virginia Polytechnic Institute, brought in a specimen from an older horizon, the Ithaca formation.

After completion of this manuscript one of us (HPB), while working over Devonian collections at the New York State Museum at Albany at the request of State Paleontologist Dr. Winifred Goldring, found a few specimens of *Drydenia* n. gen. collected by M. Sheehy and J. Van De Loo in 1895 from "Chemung" beds at Almond, Alleghany Co. This extends the geographic range of this new alga sixty or seventy miles.

Localities.—Four localities are known for these new genera. Two are the Hungerford and University Quarries about ½ mile apart on the Ellis Hollow Road 1½ miles east of Ithaca, New York. The third locality is Lick Brook, a small gorge 3 miles south of Ithaca. The fourth locality is known only as "Chemung" beds, Almond, Alleghany Co., N.Y.

Lithology.—The two quarries have a very similar lithologic succession. The rocks consist of alternating sequences of gray, arenaceous shales and gray, thin-bedded, fine-grained siltstones or "flagstones." The strata are flat lying and dip less than one degree to the south. Lateral variation in the sediments, mud balls, ripple marks and cross-bedding indicate shifting currents in moving, shallow water (Fuchs, Marshall and Lentz, 1951). The plant remains are found in the turbulent siltstone beds that were deposited in water variously estimated at between 50 and 75 feet in depth and perhaps 75 to 100 miles off the old shoreline. The fossils are always found within the siltstone and not on its surfaces in contact with the shales. They do not however lie perfectly flat. Splitting of the siltstone to expose plants gives often an undulating surface that follows the convexities or concavities of the plants as the case may be. Occasionally a single split exposes plants lying at several different horizontal planes within the siltstone. If the siltstone was formed by the action of turbidity currents (Kuenen, 1950), it seems more likely that the fossils were carried into the site of their deposition than that they grew in situ under these rather disturbed conditions. The holdfasts of *Drydenia* appear to lie in essentially the same plane as the lamina whereas if they had grown in situ, some evidence of bending of the lamina from the attached holdfast should be evident. The specimens from Almond, N.Y., are contained in a flagstone similar to that at the quarries.

Stratigraphy.—The rock strata from which the two quarry collections were made are mapped as part of the Enfield formation (Fuchs, Marshall and Lentz, 1951). This is the uppermost formation, in the Ithaca region, of the Finger Lakes stage, being part of the Senecan series and hence Upper Devonian. The strata of the Lick Brook locality are part of the Ithaca formation which underlies the Enfield in the Ithaca region. The stratigraphic position of the locality at Almond is uncertain in the absence of more precise data. Surface exposures in the region belong to the Cassadaga stage in the Chautauquan series. This is much younger than the outcrops in the vicinity of Ithaca and, if accurate, extends the vertical as well as the horizontal range of the fossils considerably. It is possible, of course, that if the exact locality were known, the plants could be shown to be older than we now believe.

Technique.—The plant remains to be described are compressions and in some instances little more than impressions. In nearly all of the specimens the compression of plant material consists of a thin, amorphous film of hydrocarbon in which no cellular pattern is discernible. Reticulae of a distinctive form mark the surface of one of the genera. Transfers following Walton's method (1923) and the use of the peel technique of Abbott (1950) and Abbott and Abbott (1952) yielded no information other than the thin film of carbonaceous material in which no structure was present.

SYSTEMATIC DESCRIPTIONS

The three genera of plants are considered to be marine algae and three generic names are proposed. One (*Drydenia*) is named for a small village near the quarries. A second genus (*Hungerfordia*) is named for the quarry in which the single specimen was found. The third (*Enfieldia*) is given in consideration of the formation in which the specimens are most abundant.

Genus DRYDENIA Fry and Banks, n. gen.

Generic diagnosis.—Marine alga; organism composed of lamina and branched filamentous holdfast; lamina varying from ovate to obovate to elliptic; base cuneate. Known from compression-impression remains of type species.

Type species.—*Drydenia foliata* n. sp.

DRYDENIA FOLIATA Fry and Banks, n. sp.
Plate 9, figures 1–10

Species diagnosis.—Lamina ranges from 10–72 mm. in width, 37–85 mm. in length. Apex of lamina in undamaged state is entire and flat, obtuse, or acute or often torn or frayed. Holdfast 1–3 mm. broad, branching as a fibrous system, up to 2–3 cm. long but averaging 1 cm. or less.

Description and discussion.—*Drydenia* consists of a lamina and holdfast. The lamina exhibits a wide range of shape and size. The range in width at the widest portion of the lamina is 10–72 mm. The range

in length is 37–85 mm. More typical sizes are 25–30 mm. wide by 45–60 mm. long. The overall shape varies from ovate to elliptic with many specimens having a distinctly cuneate base. The distal region of the lamina is extremely variable and may be flat, obtuse or acute. The widest portion of the lamina is located approximately one-half to two-thirds up from the basal holdfast region. From this widest portion down to the holdfast the outline of the lamina is straight and the margin is always entire. The upper part of the lamina is variously modified. In some specimens it appears frayed and broken into segments. Others appear flat across the top and in some instances may taper to a blunt apex. Although the margin is thus modified, the normal condition is believed to be entire. The modifications were probably caused by water action while the organism grew attached to its substratum. Further changes may also have been introduced during transport of the plants to their place of burial and fossilization.

Occurrence.—Hungerford and University Quarries ½ mile apart on the Ellis Hollow road, 1½ miles east of Ithaca, New York: Enfield formation; Finger Lakes stage; Senecan series; Upper Devonian. Lick Brook, a small gorge 3 miles south of Ithaca: Ithaca formation which immediately underlies the Enfield formation and has the same general age relationships. Almond, Alleghany Co., N.Y. in "Chemung" beds, probably Cassadaga stage, Upper Devonian.

Types.—Deposited in paleobotanical collections, Department of Botany, Cornell University. Holotype, 1302. Paratypes: 1228, 1282, 1290, 1292, 1297, 1301, 1303, 1307.

Genus HUNGERFORDIA Fry and Banks, n. gen.

Generic diagnosis.—Marine alga; dichotomously branching lobes arise at one level from a deltoid base; margin entire. Known from compression remains of type species.

Types species.—Hungerfordia dichotoma n. sp.

HUNGERFORDIA DICHOTOMA Fry and Banks, n. sp.
Plate 10, figure 1

Species diagnosis.—Maximum length of specimen 70 mm.; maximum width 73 mm.; base 13 mm. wide by 15 mm. long; the branching lobes widest at their apices, tapering sharply at their point of connection to the base.

Description and discussion.—Hungerfordia is represented by a single specimen having a maximum length of 70 mm. and a maximum width of 73 mm. Several dichotomously branching lobes appear to arise at one level from a deltoid basal region. Three of the four lobes are well developed and show two sets of dichotomies. A fourth lobe is represented by a narrow strand only and apparently it lay beneath one of the larger lobes when first deposited on the sand. It is obviously very poorly preserved. A fifth lobe seems to be indicated by the merest trace of compression material on the right hand side of the deltoid base.

All four of the major lobes are widest near their apices. They narrow sharply as they approach the point of connection with the base, and in one case little more than a thin line is present. A careful comparison of the four indicates that the width of the lobe in this region may be influenced by three factors. The first, of course, is the extent of the preservation. The second is the possibility that the lobe may have been twisted when laid on the sand and that the compression shows the thickness rather than the width of the base of the lobe. The third might be the abrasion of all except the midrib portion as in living Fucaceae (personal

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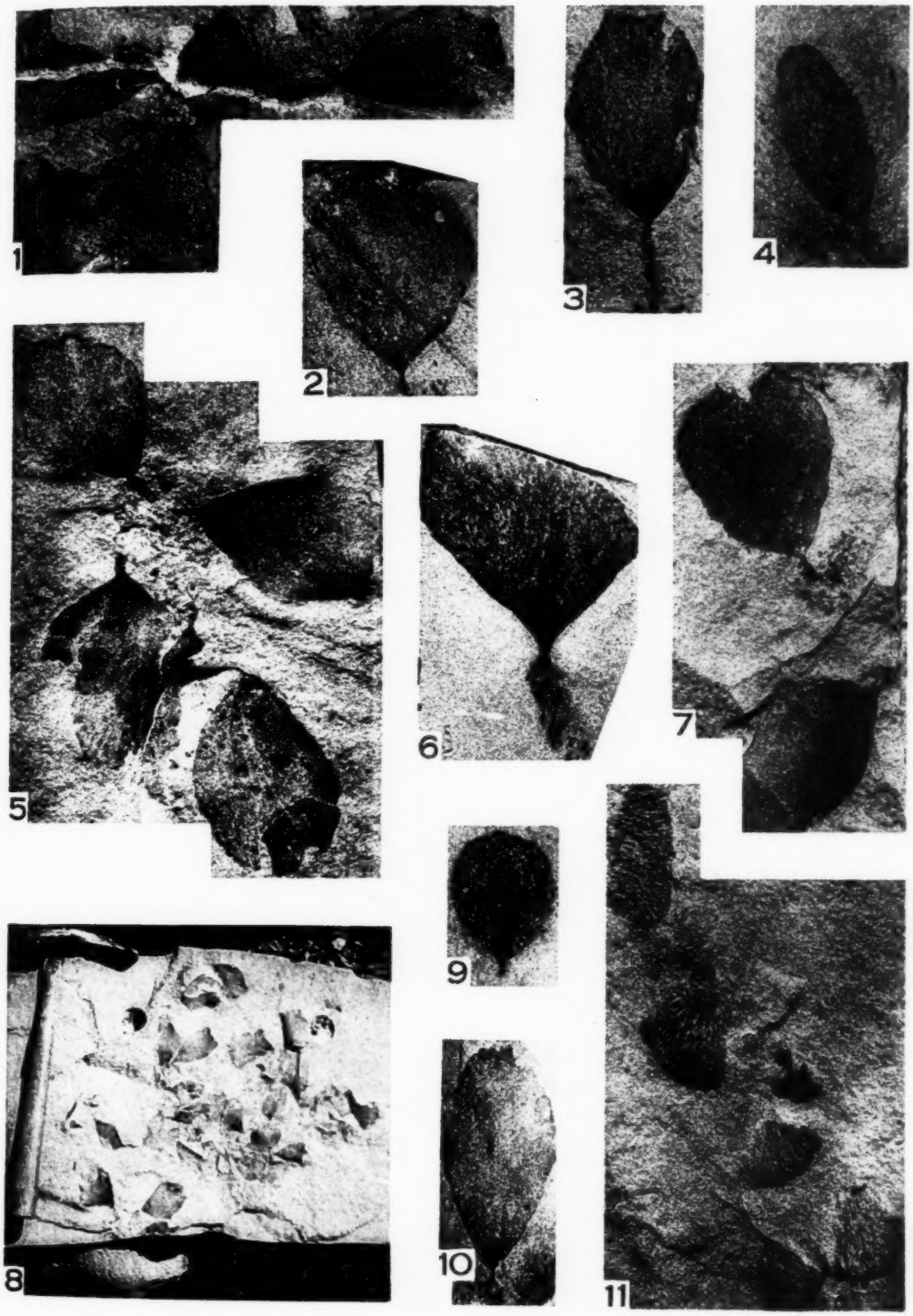
EXPLANATION OF PLATE 9

FIGS. *1–10—Drydenia foliata* Fry and Banks, n. gen., n. sp. *1–7, 9, 10,* ×½, showing variation in form of plant; note particularly details of holdfasts in figs. *2, 4, 10. 8,* photo (courtesy Dr. John W. Wells), taken in the field, of a slab showing a large number of plants on a surface, ×¼. Holotype: *10,* 1302. Paratypes: *1,* 1228; *2,* 1301; *3,* 1303; *4,* 1282; *5,* 1290; *6,* 1297; *7,* 1307; *9,* 1292. (p. 39)

11—Enfieldia mutilata Fry and Banks, n. gen., n. sp. Several fragments of the plant on a surface. Note their roughly triangular shape and the reticulate pattern. ×½. Paratype: 1276. (p. 41)



Fry and Banks, Upper Devonian Algae, New York

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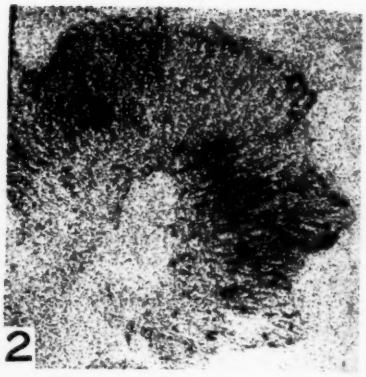
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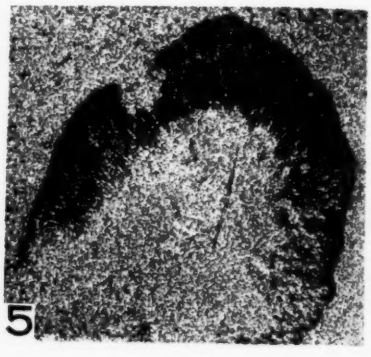
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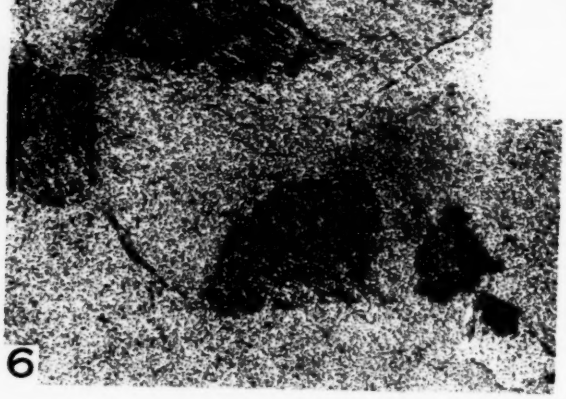
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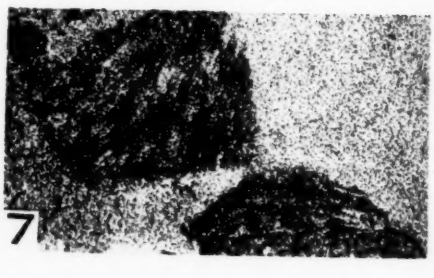
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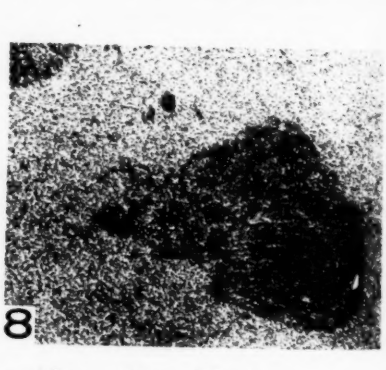
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Fry and Banks, Upper Devonian Algae, New York

communication, G. M. Smith, Dec. 22, 1953).

The lobe on the left side of the specimen is the best preserved and gives some indication of the habit of the plant. It totals 40 mm. in length and 40 mm. is its maximum width. The first dichotomy is an equal branching and occurs 23 mm. above the base of the lobe. Each of the arms produced at the fork again divides equally at 30 mm. from the base. The two dichotomies are thus close together. The ultimate tips are broad, rounded at their apex and show no sign of tapering.

The deltoid base of the specimen is 13 mm. at its maximum width and is about 15 mm. long. It is doubtful if its narrow end is a true base because the specimen simply fades into the matrix. There is no indication of a holdfast or other mode of attachment.

The margin of the specimen is entire. The uniformity of outline which thus characterizes the plant is interrupted only by the appearance of the ultimate tips of the right hand lobe. These have been preserved poorly and are obviously imcomplete.

Occurrence.—Hungerford Quarry on the Ellis Hollow road, 1½ miles east of Ithaca, New York: Enfield formation; Finger Lakes stage; Senecan series; Upper Devonian.

Holotype.—Deposited in paleobotanical collections, Department of Botany, Cornell University, No. 1164.

Genus ENFIELDIA Fry and Banks, n. gen.

Generic diagnosis.—Marine alga; complete organism roughly circular; outer margin lobed; circular central portion usually lacking or obscure; plant usually broken into wedge-shaped segments; surface characteristically marked by radially aligned reticulations. Known from compression-impression remains of type species.

Type species.—*Enfieldia mutilata*, n. sp.

ENFIELDIA MUTILATA Fry and Banks, n. sp.
Plate 9, figure 11;
Plate 10, figures 2–8

Species diagnosis.—Plant 40–50 mm. in diameter, composed of 5–8 segments; isolated segments 20–35 mm. long by 20–40 mm. wide; surface reticulae 0.5–1.5 mm. wide by 3–6 mm. long, averaging 1 mm. wide by 4.5 mm. long; both ends of reticulae terminate as points.

Description and discussion.—Remains of *Enfieldia* are sometimes found on the same rock surface as *Drydenia*. *Drydenia* in turn has been found in the Ithaca formation on the same surface as *Plumalina plumaria*, a fossil of much disputed affinity which Ruedemann (1916) placed in the Alcyonaria among the Anthozoa.

A complete plant of *Enfieldia* is approximately circular in shape, with a lobed margin and a central hole of varying size. It is possible that the central region was thin and not preserved or thin but torn away when the plant was detached from its substratum or that there never was any continuous tissue in the center of the plant. This last possibility is somewhat negated by the varying size of the central hole in the most nearly complete specimens. The number of lobes is not constant and probably varies from 5–8. The diameter of the most complete specimens is 40–50 mm.

The most important characteristic of this genus appears to be its typical appearance as wedge-shaped segments probably resulting from breakage through the indentation between lobes. These numerous fragments are wider at their outer margins and taper to approximately one-half this width. There exists, however, a great deal of variation in the shape of these pieces of the lamina. The more uniform segments are 20–35 mm. long and 20–40 mm. in maximum width.

EXPLANATION OF PLATE 10

All figures natural size.

FIG. *1*—*Hungerfordia dichotoma* Fry and Banks, n. gen., n. sp. Note the dichotomies and triangular basal portion of the plant. Holotype, 1164. (p. 40)

2–8—*Enfieldia mutilata* Fry and Banks, n. gen., n. sp. Figs. *2*, *4*, *5* illustrate the nearly circular outline of complete specimens. Note undulate outer margin. Reticulate markings are particularly well illustrated in fig. *4*. Figs. *6–8* depict the more common fragmentary appearance of the plant remains. Holotype: *2*, 1265. Paratypes: *3*, 1253; *4*, 1271, *5*, 1273; *6*, *8*, 1249; *7*, 1267. (p. 41)

The segments and entire laminae are considered to belong to the same organism. The basis for this opinion is the presence, on the compression-impression plant surfaces of numerous reticulae which are aligned with their long axis parallel to the radius of the lamina. Individual reticulae range 0.5 to 1.5 mm. in width and 3 to 6 mm. in length. The average size is 1 mm. in width by 4.5 mm. in length. Both ends of the reticulae terminate in points. The reticulae are too large to have been caused by individual cells but may have resulted from some alignment of filaments within the thallus.

Occurrence.—Hungerford and University Quarries ½ mile apart on the Ellis Hollow road 1½ miles east of Ithaca, New York; Enfield formation; Finger Lakes stage; Senecan series; Upper Devonian.

Types.—Deposited in paleobotanical collections, Department of Botany, Cornell University. Holotype, 1265. Paratypes: 1249, 1253, 1267, 1271, 1273, 1276.

DISCUSSION

It seems desirable to indicate the living groups of algae to which these fossils show some resemblance although this step raises many questions. In the first place, are the plants algae? It should be emphasized that our evidence is almost entirely gross external morphology and that proof of relationship to a given phylum is lacking. Several points have to be made clear. There are no Devonian vascular plants with any of the characters of these fossils. Devonian bryophytes are unknown unless certain capsule-like structures (.g., *Sporogonites*) are interpreted as moss capsules. Several groups of algae were already well established by Devonian time and although it is not possible to generalize concerning the evolutionary level that Devonian algae had reached, neither is it possible to exclude any algal groups from consideration merely because of the age of the rocks. Three algologists (personal communications: G. M. Smith, December 22, 1953; W. R. Taylor, December 24, 1953; G. F. Papenfuss, January 28, 1954) agree that the specimens of *Drydenia* and *Hungerfordia* resemble some algae and that *Enfieldia* might or might not be one. There are no Paleozoic algae to which these forms show any close similarity. Finally, we should mention the possibility that some Devonian algae might show many characters not found in living algae. In the intervening 290–300 millions of years many changes could have occurred.

Another aspect to be considered in drawing up a list of modern genera related to the fossils is the ecological situation in which the fossils lived. Several of the living genera most closely approached by the fossils are found in the temperate zone while others are tropical. The Middle Devonian sea is usually considered to have been warm as indicated by the uniform faunas of the limestones and coral reefs, particularly those belonging to the Onondaga formation (Ruedemann, 1939). The Onondaga was replaced by a very different sedimentation phase characterized by the deposition of muds and sands. In occasional ecologic niches amongst the overlying younger beds the included fauna is Onondaga in nature and indicates the possibility of an extension of the same warm climate on into Upper Devonian time (oral communication, J. W. Wells, January 21, 1954). These niches are found even higher in the Upper Devonian than in the beds under discussion here. On this basis, our list of modern forms should include warm-water, possibly tropical, genera.

It seems to us however that the possibility of cool currents from the north creating temperate conditions in the zones where these algae grew should not be entirely ruled out. Hence, both temperate and tropical genera are included in the lists.

Among the genera of the temperate zone, *Drydenia* approaches the brown alga *Laminaria* some of whose species are small and have well developed holdfasts. It also resembles somewhat the red algae *Porphyra*, *Gigartina* (e.g., *G. radula*), some foliose Delesseriaceae, and *Dilsea*. If *Drydenia* grew in tropical waters, some members of the green algal group Siphonales such as *Udotea* or *Avrainvillea* might be its closest relatives. The absence of calcium carbonate on the specimens does not bar the inclusion of lime-secreting algae in the list because, as is often the case in sandy deposits like these under consideration (Reudemann 1916), all the lime might have been leached out of the

plants. In the absence of detailed internal or reproductive morphology neither the algologists consulted nor we can agree on any one living genus with which to associate this alga.

Hungerfordia is much easier to match with living genera of the temperate zone than with tropical forms. The red algal genera *Gymnogongrus* and *Chondrus*, or possibly species of *Gigartina* or *Rhodymenia* and the brown algal group Fucaceae, particularly the genus *Fucus*, are the forms that the fossil resembles most closely. If tropical waters are indicated, the authors suggest the brown alga *Dictyota* as a possibility although the algologists consulted showed little enthusiasm for this choice. A second possibility is that it might have been a siphonalean green alga.

Enfieldia is the most difficult form to match with living representatives of the algae. Among warm water forms, it shows some resemblance to certain species of *Zanardinia* in the Cutleriales and *Zonaria* in the Dictyotales, both brown algal groups, and to *Acrosorium* in the red algal family Delesseriaceae. There is also the possibility that it is a member of the reticulate Siphonocladales among the green algae. The temperate zone red alga *Polyneura* of the Delesseriaceae has microscopic veins that might admit a comparison with *Enfieldia* and, on the basis of gross structure only, there is the possibility of relating it to certain brown algae such as *Ralfsia* or to some crustose coralline red algae such as *Constantinea* or *Fosliella*.

The questionable relationship of *Enfieldia* stems from its lack of striking resemblance to any living algae and its possession of a reticulate surface pattern that is not matched readily in living forms. This pattern is probably not caused by individual cells because the reticulae are too large. It is more like the surface pattern caused by air chambers in certain thalloid liverworts and, if the plant is an alga, might be caused by some arrangement of filaments. As mentioned earlier, we believe that the number of years that have elapsed since this plant lived is far more than sufficient for many changes to have occurred and that the failure to find an exact parallel in living plants should not bar its consideration as an alga.

The possibility that *Enfieldia* represents a thalloid liverwort must not be overlooked entirely. However, it seems more likely to us that an alga might stand the long transport from the shore line (75–100 miles or more) than that a liverwort would remain in this relatively good condition for so long a trip. We cannot argue on the basis that liverworts have not been reported from Devonian beds because when they do appear in Carboniferous time they look much like living genera (Walton, 1925). In time, therefore, Devonian liverworts will undoubtedly be found, but probably not so far out at sea as these specimens. Possibly, too, they may show some features indicating a lower level of evolution than Carboniferous forms.

Clearly then these Devonian algae can be likened to either temperate or to tropical genera and seem not to contribute definitively to the problem of Devonian sea climates. By recording them and indicating some of the problems surrounding their interpretation, it is hoped that additional specimens or information may be forthcoming that will offer us a solution. One petrified specimen of one of these plants would go a long way toward settling the disposition of these algae.

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NEW GENERA OF MIDDLE PALEOZOIC BRACHIOPODS

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ABSTRACT—Eight new genera are proposed, three of them belonging to the Dalmanellacea and five to the Rhynchonellacea. The German Devonian genus *Kayserella* is revised and its interior figured and described. The German Devonian genus *Mystrophora* is described in detail and compared with *Kayserella*. The revision of *Kayserella* led to the recognition of a new German Devonian genus *Phragmophora* and a new French Devonian genus *Monelasmina*. The former belongs to the Onniellidae but the latter has the structure of the Schizophoriidae. A third new genus, *Hypsomyonia*, from the Upper Devonian of Iowa has a peculiar elevated adductor platform in the brachial valve. All these genera are interesting examples of homeomorphy.

In revising the Silurian rhynchonellid genus *Stegerhynchus* Foerste it was discovered that the name included more than one genus. *Stegerhynchus* was fixed by Schuchert on *S. whitii* (Hall) but Foerste's varieties from the Silurian at Clifton, Tennessee, appear to belong to the Russian genus *Ferganella*. The Lower Devonian rhynchonellid *Rhynchonella formosa* Hall is here described as *Machaeraria*, a new genus. Four other genera of rhynchonellid brachiopods are described as new: *Fenestrirostra* from the Silurian of Anticosti; *Pegmarhynchia* from the Lower Devonian of New York; *Hyborhynchella* from the Upper Devonian (Sly Gap) of New Mexico; and *Porostictia* from the Upper Devonian (Percha) of New Mexico.

INTRODUCTION

THE odd assortment of genera described in this paper is a by-product of other studies. For years the writer has been interested in *Kayserella*, a brachiopod from the Middle Devonian rocks of Germany. This genus has hitherto been classified among the Strophomenacea where it clearly does not belong. In an effort to understand this shell the writer asked for loans of specimens from Germany but few well-preserved specimens were obtained from these sources. Better results were obtained from a loan of all orthid brachiopods from the Schultze Collection of German Devonian fossils from the Museum of Comparative Zoology, Harvard. This collection proved to be very rich in specimens of well-preserved material. Not only were the specimens abundant and well preserved but it is possible that Schnur's types are actually preserved in the collection.

Specimens of *Orthis lepida* and *O. plicatella*, both species of Schnur, contained in their trays the type marker used by the Museum of Comparative Zoology. In order to be sure that these were the types, the writer asked a leading Museum in Germany where the Schnur types are located. The reply stated that the types were not in that institution but they might be in another German museum. Inquiry of the next institution brought the suggestion that they might be in still another. They were not located in any of four German institutions approached on the subject. It is possible therefore that the actual types are at Harvard, but definitie corroboration of this has not been forthcoming.

Unfortunately, comparison of Schnur's figures with the specimens purported to be his types is inconclusive. No specimens were found that could be definitely matched with his figures. All of Schnur's illustrations are drawings with little detail; consequently, it would be difficult to match specimens precisely unless some distinctive fracture or other mark was preserved in specimen and drawing. In the instances of the dalmanelloid brachiopods no such marks were found on specimens or drawings. In spite of these difficulties the specimens are typical ones and may be the types. *Orthis lepida* is marked as the possible holotype because it was the only specimen in the collection labeled as that species and had a reference to Schnur's description on the label.

The rhynchonelloid genera described herein, which the writer recognizes as new, resulted from studies of collections of Hel-

derberg, Sly Gap and Percha (the last two Upper Devonian) fossils. In making comparison of the Helderberg genus *Machaeraria* (*R. formosa*) the writer discovered the difficulties with the Silurian genus *Stegerhynchus* of Foerste. Comparison of leiorhynchoid or nudirostroid rhynchonellids in the study of the Sly Gap genus *Hyborhynchia* led to the discovery of the generic characters of *Fenestrirostra*.

It is a pleasure to state here the writer's indebtedness to Dr. Harry B. Whittington, of the Museum of Comparative Zoology, Harvard, for the loan of the superb material from the Schultze Collection.

SYSTEMIC DESCRIPTIONS

Superfamily DALMANELLACEA
Family MYSTROPHORIDAE Schuchert & Cooper, 1931
Genus KAYSERELLA Hall & Clarke, 1892
Plate 11, B, figures 12–23

Kayserella HALL & CLARKE, Paleontology New York, vol. 8, pt. 1, p. 259, 1892.

This genus has never been understood since its proposal by Hall and Clarke in 1892. These authors named as type of the genus *Orthis lepida* Schnur which was described in 1853 but was revised by Kayser in 1871. Kayser's revision lead to an erroneous conception of the species and the genus. *Kayserella* is evidently a rare genus because it is uncommon in Germany where it was first described and is uncommon in other parts of Europe. Until the present writing the genus was unknown in North America.

The name *Kayserella* must be restricted to species congeneric with the type: *K. lepida* (Schnur). It is therefore necessary to examine the type species and its nomenclature in detail. Kayser (1871, p. 617) discusses three species which he believes to be conspecific. The first is *Orthis testudinaria* (Schnur, 1853, p. 212, pl. 37, fig. 3, not Dalman, 1828) which is characterized by a keeled pedicle valve, sulcate brachial valve and the delthyrium covered by a convex plate. The second is *Orthis plicatella* (Schnur, 1853, plate 38, fig. 4, not Hall, 1847) which was figured but not described and which is very similar to the previous species (*O. testudinaria* Schnur). The third is *Orthis lepida* Schnur (1853, p. 218, pl. 45, fig. 9) which Kayser regarded as the young of the preceding species (*O. plicatella* Schnur). Kayser selected the name *O. lepida* for the revised species including all of Schnur's first two species because *O. testudinaria* was neither conspecific nor congeneric with Dalman's species and the name *O. plicatella* was preoccupied by Hall's species of the same name which is now the type species of *Plectorthis*.

In 1892 Hall and Clarke named *O. lepida* Schnur, called *Streptorhynchus? lepida* by Kayser, as type of their new genus *Kayserella* in honor of Kayser for his notable work on the Devonian of Germany. These authors accepted Kayser's revision of the species (which included the three species proposed by Schnur) and noted the salient features of their genus as: inequivalved, the pedicle valve having the greater depth, the "deltidium" in the pedicle valve, and the enormous septum inside the brachial valve. The genus was said to have affinities with *Streptorhynchus* and its allies even through it was punctate (not endopunctate).

Examination of Schnur's specimens now shows clearly that *Orthis lepida* is not the young of *O. testudinaria* Schnur (not Dalman) or of *O. plicatella* Schnur (not Hall). The specimens examined bear the label: "*Orthis lepida* Schnur, Pal. III, t. 44, fig. 9." The plate reference on the label is an error because figure 9 on plate 44 is a large *Athyris*. Figure 9 on plate 45 is *Orthis lepida*. The specimen examined is smaller than Schnur's figure but agrees in being deeply sulcate. The figure however, if it is of the specimen in question, is erroneous in other respects too, the beak of the pedicle valve is visible in the brachial view which is not true of the figure. The specimen has an open foramen, is differently proportioned than either *O. testudinaria* Schnur (not Dalman) or *O. plicatella* Schnur (not Hall). A specimen identical to this one, from a lot erroneously called *Orthis testudinaria* Dalman was heated in a blast lamp and the shell removed to show the internal structure. The brachial valve is provided with the huge septum, the cardinal process is bilobed and the brachiophores are supported by curving plates that unite with the floor of the valve and the median septum to form a short but prominent cruralium similar to that of *Mystro-*

phora. The pedicle muscle field is wide and short and has a wide adductor field. These features are quite distinct from those of *Orthis testudinaria* Schnur (not Dalman) and *O. plicatella* Schnur (not Hall) in which no cruralium occurs, the brachiophores being unsupported except for excess shell deposit. *Kayserella* may therefore be redefined on the basis of *O. lepida* Schnur as follows:

Dalmanelloid in appearance, unequally biconvex, usually small, somewhat wider than long, hinge narrower than the midwidth; pedicle valve subcarinate; brachial valve deeply sulcate; delthyrium open; shell endopunctate.

Pedicle valve interior with shallow delthyrial cavity, muscle field short and wide, adductor track wide. Brachial valve interior with brachiophores long, supported by curving plates that unite with the posterior end of the spetum to form a cruralium; median septum long, elevated, dividing the valve into halves. Cardinal process with bilobed myophore supported by a long slender shaft.

Kayserella as thus defined is closer to *Mystrophora* of described genera than to any other dalmanelloid. It differs from *Mystrophora* in shape and lacks the short median septum. In the pedicle valve it has a smaller, and more nearly sessile, cruralium than that of *Mystrophora*.

Skenidium fallax Gürich (1896, p. 236, pl. 10, fig. 9) from the Devonian of Poland, which is described from a brachial interior only, appears to be referrable to *Kayserella*. Gürich implies relationship to *Mystrophora* because he places that name in the synonymy of *Skenidium* and it is the only name so placed. The illustrated specimen does not belong to *Mystrophora* because it is widehinged with rounded cardinal extremities and has cardinalia like those of *Kayserella*.

Types.—Holotype (?) MCZ 9400; figured hypotypes MCZ 9401a, b.

KAYSERELLA AMERICANA Cooper, n. sp.
Plate 11, C, figure 24–29

Shell small, biconvex, dalmanelloid in appearance, wider than long and semielliptical to subcircular in outline. Sides and anterior margin rounded; anterior commissure gently sulcate. Surface fascicostellate, costellae numbering two to four in 1 mm. at the front margin.

Pedicle valve gently convex in lateral profile; broadly convex in anterior profile and with the median region somewhat narrowly convex to form a low fold. Umbonal and median regions narrowly swollen, the swelling continuing anteriorly to the front margin but in diminishing degree. Flanks gently convex and with moderately steep slopes to the margins. Interior with short oblique dental plates, a broad, shallow delthyrial cavity, elongate diductor scars and broad adductor field.

Brachial valve evenly and moderately convex in lateral profile; broadly and gently convex in anterior profile and with the median region marked by a broad, shallow depression. Umbonal and median regions gently swollen; umbo marked by a shallow sulcus that extends to the anterior margin, widening in its passage but shallow throughout its length. Flanks gently swollen. Interior with short chamber formed by brachiophore plates and attached to the median septum; notothyrial chamber with cardinal process on its floor; cardinal process bilobed, often double-shafted posteriorly and often, in adults, divorced from the main shaft. Median septum thin, rising to a point near the valve middle and descending to the anterior margin thus dividing the shell into halves. Adductors evidently attached to the median septum.

Measurements in millimeters:

	Length	*Brachial length*	*Midwidth*	*Hinge width*	*Thickness*
Paratype (pedicle valve) 123347a	5.4	?	7.4	5.4	1.2?
Paratype (brachial valve) 123347b	?	5.3	6.8	4.3	0.6?
Holotype (brachial valve) 123347c	?	5.3	6.4	5.3	?

Types.—Holotype USNM 123347c; figured paratypes USNM 123347a, b, g, k; unfigured paratypes USNM 123347 d-f, h, j, l, m.

Horizon and locality.—Stony Hollow member (upper 10 feet) of the Marcellus formation, in the railroad cut 2.1 miles southeast of Stony Hollow, Rosendale (15 minute) quadrangle, New York.

Discussion.—*Kayserella americana* differs from *K. lepida* in shape, being rounder than the German shell. It is also less strongly

keeled on the pedicle valve and is consequently less strongly sulcate. *K. americana*, so far as known, is a rare species found only at the one locality. Its occurrence in a fauna that is coeval with the Cherry Valley fauna is interesting because the latter also contains exotic elements of European affinity.

Genus MYSTROPHORA Kayser, 1871
Plate 11, E, figure 39–50

Mystrophora KAYSER, 1871, Zeitschr. deutsch. geol. Gesell., vol. 23, pp. 612–614, pl. 13, fig. 5, ——SCHUCHERT and COOPER, 1932, Mem. Peabody Mus. Nat. Hist., vol. IV, pt. 1, p. 131, pl. 16, figs. 1–5, t. f. 20, 21,

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EXPLANATION OF PLATE 11

A. *Hypsomyonia stainbrooki* Cooper, n. gen., n. sp. (p. 53)

FIGS. *1–11—1–5*, Respectively posterior, anterior, side, brachial and pedicle views of the holotype, ×5, USNM 123345a; *6–8*, interior of brachial valve, respectively partially tilted to the side, anterior, and full views showing the muscle platform, ×5, USNM 123345b; *9–11*, respectively posterior, anterior and interior views of another brachial valve showing the widely divergent and long brachiophores, cardinal process and muscle platform, ×7.5, USNM 123345c.

Independence shale on the Poor Farm property, 1½ miles northeast of Independence, Iowa.

B. *Kayserella lepida* (Schnur) (p. 46)

FIGS. *12–16*, Respectively posterior, anterior, pedicle, side and brachial views, ×2, Holotype (?) MCZ 9400.

Middle Devonian (crinoid beds), Gerolstein, Eifel, Germany.

17–23—17–20, Respectively anterior, brachial, side and pedicle views of another complete specimen, ×2, MCZ 9401a; *21, 23*, pedicle and brachial views of an anterior mould showing median septum track and impression of the cruralium, ×2, MCZ 9401b; *22*, plasticine impression of the brachial mould showing a replica of the interior with its cruralium and high median septum, ×2.

Middle Devonian (crinoid beds), Prüm, Eifel, Germany.

C. *Kayserella americana* Cooper, n. sp. (p. 47)

FIGS. *24–29—24*, Impression of the brachial interior showing the median ridge, impression of the cruralium and the double slot of the cardinal process, holotype, ×3, USNM 123347c; *25*, plasticine replica of the interior of the preceding specimen, ×3, showing cruralium and bilobed cardinal process; *26*, rubber cast (the cast shows only the lower part of cruralium) showing replica of the exterior of the pedicle valve, ×3, USNM 123347k; *27*, side view of the median septum of a broken specimen, ×3, paratype USNM 123347g; *28*, plasticine replica of the exterior of a brachial valve, ×3, paratype USNM 123347b; *29*, impression of the pedicle interior showing wide slots of the short, thick dental plates and muscle scars, ×3, paratype USNM 123347a.

Stony Hollow member (upper 10 feet) of the Marcellus formation, railroad cut 2.1 miles southeast of Stony Hollow, Rosendale (15 minute) Quadrangle, New York.

D. *Monelasmina deshayesi* (Rigaux) Cooper, n. gen. (p. 53)

FIGS. *30–34*, Respectively pedicle, side, posterior, anterior and brachial views of a complete specimen, ×3, hypotype USNM 61224a.

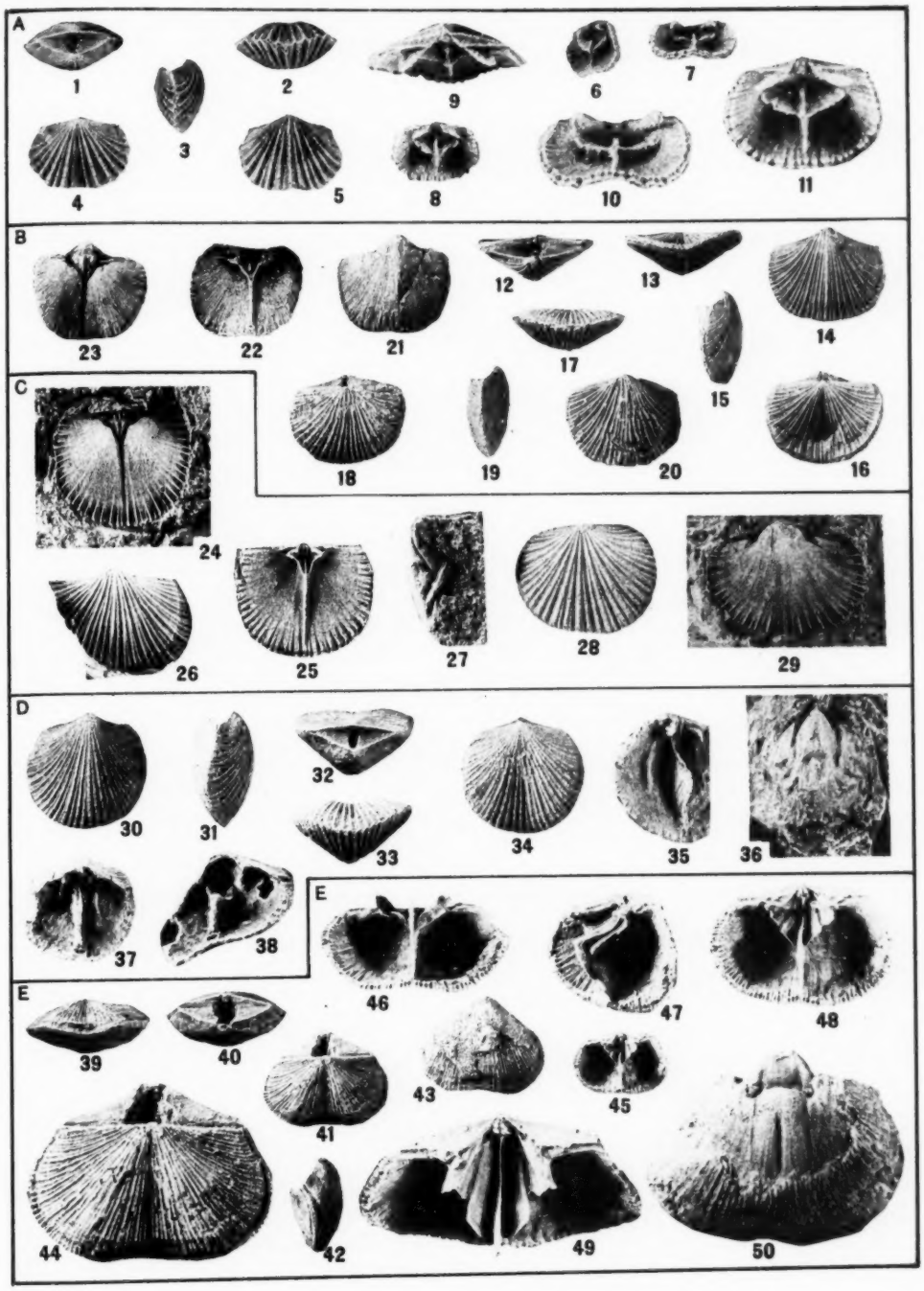
37, 38, Brachial interior in full view and tilted to show grooved median septum and flaring brachiophore plates, ×3, hypotype USNM 61224b.

Upper Devonian (Frasnian), Beaulieu, Boulonais, France.

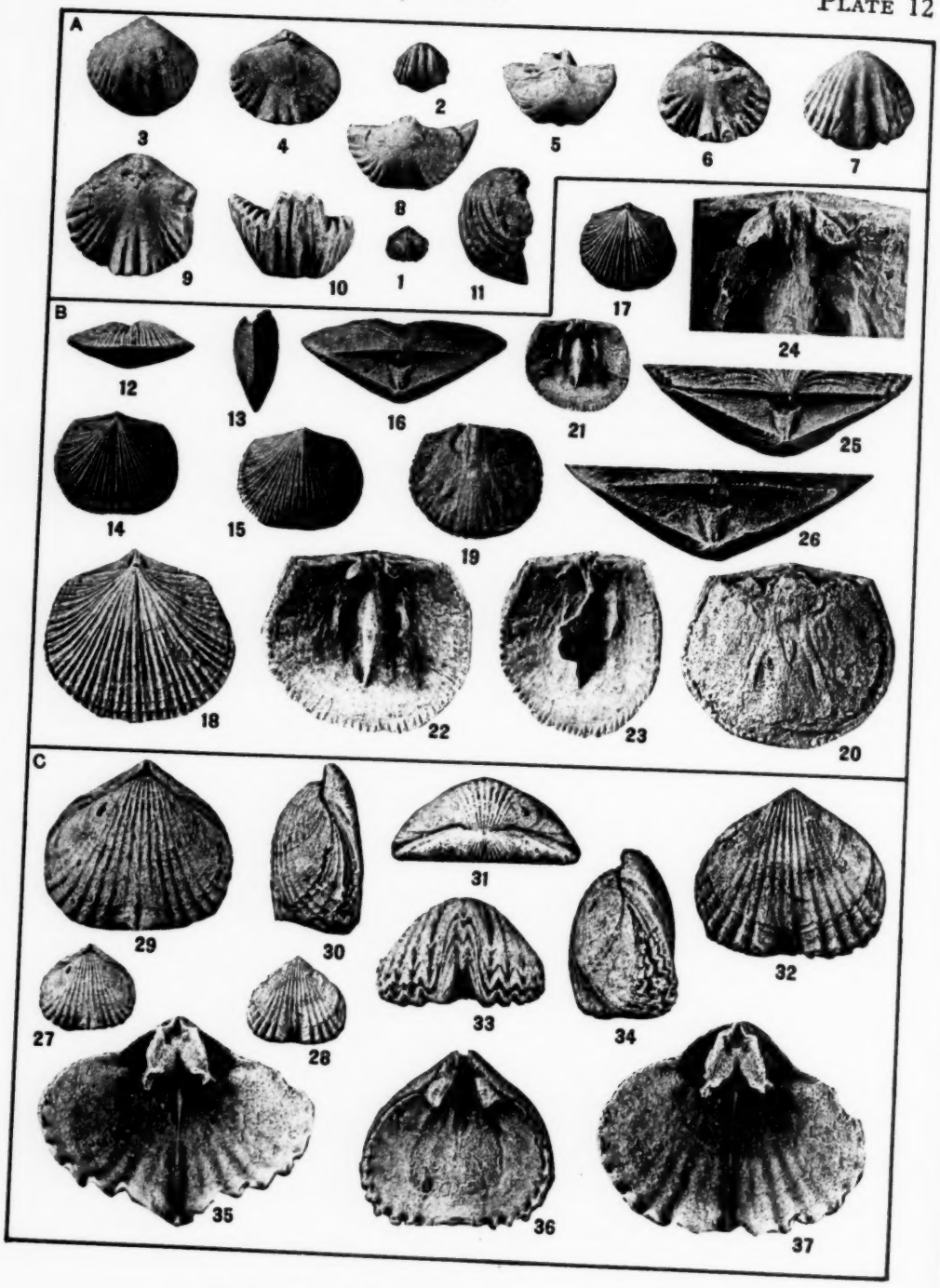
35, 36—38, Brachial interior tilted to the side to show the high median septum, the brachiophores and ridge on the side of the adductor field, ×4, hypotype USNM 123349a; *36*, impression of interior of pedicle valve showing muscle field, ×3, hypotype USNM 123349b. Upper Devonian (Frasnian), Ferques, Pas du Calais, France.

E. *Mystrophora areola* (Quenstedt) (p. 48)

FIGS. *39–50—39–43*, Respectively anterior, posterior, brachial, side and pedicle views of a large individual, ×1, hypotype MCZ 9403a; *44*, brachial view of the preceding, ×2, showing details of the ornamentation; *45*, interior view of brachial valve, ×1, hypotype MCZ 9402; *46–48*, respectively anterior tilted, partial side, and interior views of the preceding brachial valve, ×2, showing median septum and long cruralium attached to the septum; *49*, posterior view of the preceding brachial valve showing cardinalia, ×3. Note small articulating process on the brachiophore on the reader's left. *50*, impression of a pedicle interior showing small diductor scars, broad adductor field and short median septum, ×2, hypotype MCZ 9403b.



Cooper, Middle Paleozoic brachiopods



Cooper, Middle Paleozoic brachiopods

Kayser well described his genus as regards exterior details but some features of the interior were left uncertain. This is true also of the description by Schuchert and Cooper, although they increased our information of the interior. Excellent specimens from the Museum of Comparative Zoology, Harvard, make it possible to describe and figure the interior of the brachial valve in greater detail than before.

The exterior of *Mystrophora* is distinctive and different from that of *Kayserella*, which also has a cruralium. The distinctive feature of the exterior is the strongly pentagonal form, with the long palintrope of the pedicle valve and the hinge much narrower than the greatest shell width which is at about the middle. The cardinal extremities are obtusely angular. The anterior commissure is strongly emarginate.

In order to obtain some idea of the pedicle muscles the shell of an adult specimen was burned and scraped off. (See pl. 11, fig. 50.) The muscle field is small and is slightly elevated on a thickened floor. The diductor scars are somewhat tear-shaped and are small and narrow. The adductor field on the other hand is broad. Another feature of the pedicle interior is the short median septum lying anterior to the muscle field and at about the center of the valve. This separates two thick, parallel vascula media. The dental plates are short and divergent and a small plate is situated at the apex. This is sunk below the level of the interarea and is suggestive of a similarly placed plate that

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EXPLANATION OF PLATE 12

A. *Hyborhynchella bransoni* Cooper, n. gen., n. sp. (p. 62)

FIGS. *1–11—1*, Brachial view of a medium-sized individual, ×1, paratype USNM 123343a; *2*, pedicle view of a larger individual with one costa in the sulcus, ×1, paratype USNM 123343c; *3, 4*, pedicle and brachial views of a nearly perfect specimen having two costae in the sulcus, ×2, paratype USNM 123344a; *5–7*, respectively posterior, brachial and pedicle views of a well-preserved specimen with a single costa in the sulcus, ×2, holotype USNM 123344b; *8–11*, respectively posterior, brachial, anterior and side views of a large specimen having three costae in the sulcus, ×2, paratype USNM 123344c.

Sly Gap formation, 3 miles east of the north end of Alamogordo, Indian Wells Canyon, NE ¼, sec. 14, T. 16 S., R. 10 E., Otero County, New Mexico.

B. *Phragmophora schnuri* Cooper, n. gen., n. sp. (p. 52)

FIGS. *12–18, 25, 26—12–15*, Respectively anterior, side, brachial and pedicle views of a large, nearly perfect specimen showing slit-like posterior part of median sulcus in brachial valve, ×1, holotype MCZ 9405b; *16*, posterior view of another well-preserved individual showing notodeltidium and elongate foramen, ×2, paratype MCZ 9405a; *26*, same further enlarged to show the foramen better, ×3; *17*, brachial view of a smaller specimen showing ornament and short, slit-like median sulcus, ×1, paratype MCZ 9405c; *25*, posterior of the preceding showing notodeltidium, narrowly oval, longitudinal foramen and myophore lobes of cardinal process; *18*, brachial view of specimen illustrated in fig. *26*, showing ornamentation, ×2.

Middle Devonian (crinoid beds), Gerolstein, Eifel, Germany.

19–24—19, Impression of the pedicle interior showing muscle scars and more indistinctly, the pallial trunks, ×1, paratype MCZ 9404a; *20*, impression of a pedicle valve showing the vascula media. The small oval boss between the posterior ends of the vascula media is the tip of the median septum. The matrix filling this specimen was cleaned out to produce the interior shown in figs. *21–24*. Paratype MCZ 9404b, ×2. *21*, Interior of the brachial valve, ×1, showing median septum, same specimen as preceding, paratype MCZ 9404b; *22, 23* same as preceding in interior and side views showing median septum and dalmanelloid cardinalia, ×2; *24*, cardinalia of preceding enlarged, ×3, to show brachiophores, double-shafted cardinal process, and elliptical cross-section of crus on right side.

Middle Devonian (crinoid beds), Prüm, Eifel, Germany.

C. *Pegmarhynchia zimmi* Cooper, n. gen., n. sp. (p. 59)

FIGS. *27–37—27, 28*, Brachial and pedicle views of the holotype, USNM 108208a; *29–32*, respectively brachial, side, posterior and pedicle views of the holotype, ×2; *33, 34*, anterior and side views of another complete specimen showing sulcus and stouter profile than that of the holotype, ×2, paratype USNM 108208e; *35, 37*, respectively tilted and interior views of the brachial valve showing the cardinalia, USNM 108208d; *36*, interior of the pedicle valve showing large muscle area and corrugated teeth, ×2, paratype USNM 108208b.

Glenerie formation, on U. S. highway 9W at Glenerie, New York.

occurs in other punctate genera, such as *Pionodema*.

An exceptionally well-preserved brachial valve showing nearly all details of the interior permits an expanded description of this interesting genus.

Cardinal process.—This consists of two bosses in the apex which are supported by a short shaft that unites with the median septum.

Brachiophores.—These are long blades gently crescentic in cross-section that lie obliquely under the edge of the delthyrium. The free end is bluntly pointed and the edge facing the interior of the brachial valve is cemented to the edge of the cruralium.

Cruralium.—This is a shallow spoon-like plate consisting of an inner and outer part. The outer parts are shorter than the inner one and are cemented to the brachiophore edge on the outside and to the inner part of the cruralium on the inside. The inner element of the cruralium consists of two long gently concave plates that are cemented on their inner edge to the side of the median septum and on their outer edge to the short outer elements of the cruralium. The junction of these two elements is marked by a longitudinal, elevated suture line. The edge of the septum facing the pedicle valve divides the cruralium into two parts. The cruralium was evidently the seat of adductor attachment and some traces of the muscle scars are visible.

Median septum.—This is a vertical septum running the full length of the valve and, when viewed from the side, forming a triangle with its small apex at the beak, and its free edge parallel to the inner surface of the pedicle valve. The septum is so strongly elevated that it divides the inner chamber of the shell into two parts. The free edge of the septum facing the pedicle valve extends into the cavity of the cruralium.

Articulation.—The outer edge of the brachiophore and the inside of the valve form a deep socket which is further bounded by thin socket plates. A small accessory tooth which articulates with the crural fossette in the tooth of the pedicle valve is situated on the sloping side of the brachiophore just anterior to the sockets.

Mystrophora differs from *Kayserella* in the form and outline of the valves. *Kayserella* is generally more nearly circular or elliptical in outline rather than pentagonal and the hinge is usually wider in proportion to the width than that of *Mystrophora* and the cardinal extremities less angular. Inside the pedicle valve *Kayserella* lacks the short median septum. The chief differences between the two genera are inside the brachial valve. The cruralium of *Kayserella* is shallower and shorter than that of *Mystrophora*. The cruralium of *Kayserella* is not divisible into four plates with sutures between, and the margin of the cruralium is entire. It is evident from the structure of these two genera that they belong in the same family, Mystrophoridae Schuchert and Cooper, 1931.

Types.—Figured hypotypes MCZ 9402, 9403a, b.

Family ONNIELLIDAE ÖPIK, 1933

Genus PHRAGMOPHORA Cooper, n. gen.

(Gr. phragmos, partition; phoros, to bear)

Subquadrate to subcircular in outline, dalmanelloid in general appearance; inequivalve, the pedicle valve having the greater depth; profile sublenticular; commissure sulcate to rectimarginate; pedicle valve subcarinate; hinge narrower than the mid-width; interarea moderately long; delthyrium covered by a narrowly convex pseudodeltidium; foramen subapical, elongate and narrowly oval. Surface multicostellate. Shell substance endopunctate.

Pedicle interior with shallow delthyrial cavity; dental plates flaring, short and stout. Adductor track narrow; diductor impressions large; vascula media prominent extending from anterior ends of diductors slightly obliquely to the front margin on each side of the elongate trough produced by the carination of the pedicle valve. Lateral vascula extending obliquely anterolaterally from the ovarian impression.

Brachial interior with notothyrium filled by a bilobed cardinal process supported by a cleft shaft continuous with the strongly elevated median septum; brachiophores short, stout, oblique blades supported by shell deposited on their inner surfaces; brachiophores narrowly elliptical in cross-section; adductor field elongate, deeply impressed and with thickneed edges.

Type species.—*Phragmophora schnuri* Cooper, n. sp.

Discussion.—The salient features of this genus are the dalmanelloid form and profile, the *Levenea*-like cardinalia and the large, elevated median septum. The interior features separate it from other *Kayserella*-like genera.

Phragmophora differs notably from *Mystrophora* and *Kayserella* in having no cruralium. In the latter two genera the supporting plates of the brachiophores form a more or less deep chamber united to the median septum or to the septum and the floor of the valve. In *Phragmophora* on the other hand the brachiophores are supported by shell substance deposited on their inner surface and the notothyrial cavity is occupied by a double-shafted, bilobed cardinal process. Thus the interior of *Phragmophora* relates the genus to the Onniellidae rather than the Mystrophoridae.

Phragmophora resembles *Monelasmina* externally in the dalmanelloid form but the cardinalia of the two are entirely different. *Monelasmina* has the cardinalia of the Schizophoriidae and thus belongs in an entirely different family group from that of *Phragmophora*.

The definition of the exterior of *Phragmophora* is the same as that of *Kayserella* as proposed by Hall and Clarke. Their definition was based on Kayer's description of *Orthis lepida* Schnur which, in turn, was based on *Orthis testudinaria* Schnur (not Dalman) because Kayser believed the former species to be the young of *O. plicatella* Schnur (not Hall) = *O. testudinaria* Schnur.

A feature of the anatomy of *Phragmophora* which needs special emphasis is the "pseudodeltidium." It is the presence of this feature which, when masquerading as *Kayserella*, led to the placement of these shells in association with *Streptorhynchus* and its allies. This was done in spite of the fact that the shell is endopunctate as in the Dalmanellacea, Terebratulacea and Terebratellacea. Actually, this is the only dalmanelloid at present known to the writer which has a "pseudodeltidium," a fact remarked by Kozlowski (1929, p. 89).

Careful study reveals the fact that this so-called "pseudodeltidium" is more like the true deltidium of von Buch than it is like the pseudodeltidium of Bronn. The form of the plate in *Phragmophora* with its strong arch over the delthyrium is like that of the characteristic pseudodeltidium but its origin is different from that of the genuine pseudodeltidium. The arched plate in *Phragmophora* appears to have originated from the union of two lateral plates that grow obliquely upward from the sides of the delthyrium and unite in the middle without visible suture on the exterior surface. Specimens examined show several stages in this development from an open delthyrium to the disjunct plates and then to a solid deltidial plate. The specimen (MCZ 9405j) with open delthyrium is well grown (9.4 mm. long and 10.9 mm. wide) and the margins of the delthyrium are so smooth and clean that the lateral plates could not have been broken off in burial or post-burial events. Specimens MCZ 9405i and MCZ 9405e show the disjunct plates. Three specimens show only one or the other of the lateral plates with a smooth margin on the opposite side of the delthyrium.

One of the interesting and significant features of the "pseudodeltidium" of *Phragmophora* is the foramen. In the development of the plate the pedicle foramen is first formed by union of the anterior ends of the lateral plates and then by shell growth gradually restricted apically to obsolescence. The elongate, slit-like form of the foramen in the first place led to the suspicion that this plate was not a normal pseudodeltidium such as that characteristic of the strophomenoid brachiopods. The elongate slit results from the union of the lateral plates at their distal end. The foramen is then gradually restricted by filling in a posterior direction until it becomes a small, round hole at the apex which may be surrounded by a small lip on the lateral and anterior sides (specimen MCZ 9406b). The foramen of specimen 9406c appears to be completely plugged.

It is evident therefore from the foregoing remarks that the pseudodeltidium of this genus, which is actually the source of the description of Hall and Clarke's *Kayserella*, is not to be confused with that structure as it is exhibited in the Orthotetinae. The plate results from the fusion of lateral plates in a

manner similar to von Buch's description of the origin of the deltidium (s.s.). The lateral plates of the Orthacea are suggestive of the deltidial plates of the Rhynchonellacea but the lateral plates of *Phragmophora* grow at an angle to the interarea and are thus different from the orthid lateral plates. The deltidial plate of *Phragmophora* is therefore here termed the *notodeltidium* from the Greek nothos = spurious.

In addition to the new species of *Phragmophora* named below, a species from Poland proposed by Gürich (1896, pp. 232) is referred here. The brachial interior figured by Gürich (pl. 10, fig. 10c) shows the characteristic dalmanelloid cardinalia and high median septum so characteristic of *Phragmophora*. It is doubtful, however, if the pedicle interior (pl. 10, figs. 5a, b) assigned to this species belongs to *Phragmophora*. The valve is not characteristically keeled and the internal markings are not right. The specimen figured by Gürich as *Kayserella lepida* (pl. 10, 13) also has the cardinalia of *Phragmophora*.

PHRAGMOPHORA SCHNURI Cooper, n. sp.
Plate 12, B, figures 12–26; plate 14, A, figure 1–7

Orthis testudinaria SCHNUR, 1853, Palaeontographica, Bd. 3, p. 212, pl. 3, figs. 3 a–c; Nachtrage p. 242, pl. 38, figs. 4 a–c = *O. plicatella* Schnur.
O. plicatella SCHNUR, 1854, idem., p. 254 (plate legend), pl. 38, figs. 4 a–c.
Kayserella lepida SCHUCHERT & COOPER, 1932, not Schnur, Mem. Peabody Mus. Nat. Hist. vol. IV, pt. 1, p. 132, pl. 16, figs. 7, 8, **10.**

Shell attaining a width of about ¾ inch, subrectangular in outline; hinge narrower than the greatest width which is at about the middle; sides rounded; anterior margin broadly rounded to subtruncate; anterior margin gently and somewhat narrowly sulcate in the young, rectimarginate in large adults. Inequivalve, the pedicle valve deeper than the brachial valve. Surface multicostellate, costellae increasing by bifurcation and implantation. Median carina occupied by a single costella in the posterior third which increases to three anteriorly. Interarea moderately long, apsacline. Notodeltidium narrowly convex; foramen variable when present, longitudinally oval to round and minute.

Pedicle valve moderately convex in lateral profile; subcarinate in anterior profile. Umbo somewhat narrowly carinate, but the carination flattening anteriorly and becoming faint or disappearing near the valve middle. Anteromedian region flattened to slightly rounded. Posterolateral slopes moderately steep; posterolateral extremities slightly deflected in the direction of the pedicle valve. Anterolateral slopes flattened, gentle.

Brachial valve most convex in the posterior half when seen in lateral profile, somewhat flattened in the anterior half; anterior profile broadly convex, but narrowly sulcate medially. Umbo sulcate, sulcus a narrow slit to about the valve middle, widening and flattening anteriorly to obsolescence at the front margin of adults. Flanks bounding sulcus moderately and somewhat narrowly convex in the posterior half, becoming broad and gentle anteriorly. Posterolateral slopes short and moderately steep; posterolateral extremities somewhat flattened.

Interior as defined for the genus.

Measurements in millimeters:

	Length	*Brachial length*	*Mid-width*	*Hinge width*	*Thickness*
Holotype	14.9	13.8	18.0	13.2	6.7

Types.—MCZ 9405b; figured paratypes MCZ 9404a; b; MCZ 9405a, c, h, j; unfigured paratypes MCZ 9405d-g, USNM 123852a-d.

Horizon and locality.—Middle Devonian (crinoid beds), Gerolstein, Eifel, Germany.

Discussion.—This species, formerly called *Orthis testudinaria* Schnur (not Dalman) served as the source of information for the genus *Kayserella*. As shown above it is not related to that genus. It differs from *Orthis lepida* Schnur in larger size, different proportions, narrower sulcus and less carinate pedicle valve. Actually, *O. lepida* Schnur was regarded as the young of *Phragmophora schnuri* but the two are now known to be unrelated.

Genus HYPSOMYONIA Cooper, n. gen.
(Gr. hypsos, elevated; mys, muscle)

Shell small, dalmanelloid in appearance, subelliptical in outline, wider than long.

Anterior commissure sulcate. Surface costellate; shell substance endopunctate.

Pedicle valve with long interarea and open delthyrium; interior with dental plates obsolete; teeth strong; muscles not deeply impressed.

Brachial valve with long, sharply pointed and widely divergent brachiophores bounding deep and wide sockets; brachiophore plates plastered on the side of the shell wall and anterior to them a broad, shallow, rhomboidal adductor muscle platform supported above the floor of the valve by a strong median septum; cardinal process bilobed and with a long shaft continuous with the median septum in the young but discontinuous in adults.

Type species.—*Hypsomyonia stainbrooki* Cooper, n. sp.

Discussion.—This genus is characterized by lack of dental plates in the pedicle valve and the broad rhomboidal adductor plate supported by a low median septum in the brachial valve. The genus is suggestive of *Mystrophora* but the known members of that genus have a deeper concave chamber at the posterior and a much larger and higher median septum.

HYPSOMYONIA STAINBROOKI Cooper, n. sp.
Plate 11, A, figure 1–11

Shell small, dalmanelloid in appearance, wider than long with rounded sides and the maximum width at about the middle; anterior commissure broadly and fairly deeply sulcate. Hinge narrower than the greatest shell-width. Pedicle valve deeper than the brachial valve. Costellate, about 19 costellae along the margin of a large adult.

Pedicle valve moderately convex in lateral profile and with the maximum convexity in the posterior half, anterior half somewhat flattened. Anterior profile broadly and gently convex. Umbo swollen; median region swollen and marked by a median rib that extends from beak to anterior margin and with its associated lateral costellae forms an ill-defined fold. Flanks swollen and with steep posterolateral slopes.

Brachial valve gently convex in lateral profile, broadly and moderately convex but with depressed median region in anterior profile. Umbo swollen; sulcus originating on the umbo and widening and deepening anteriorly to the front margin where it occupies somewhat less than half the width. Sulcus occupied by two strong costellae and occasional finer ones. Flanks somewhat narrowly swollen; slopes to cardinal extremities short and steep.

Measurements in millimeters:

	Length	*Brachial length*	*Mid-width*	*Hinge width*	*Thickness*
Holotype	2.1	1.9	2.9	2.2	1.4

Types.—Holotype USNM 123345a; figured paratypes: USNM 123345b, c.

Horizon and locality.—Independence shale, at the Poor Farm, 1½ miles northeast of Independence, Iowa.

Discussion.—No other species of this genus is known to which this one can be compared. *Hypsomyonia* occurs with *Aulacella infera* (Calvin), the young of which strongly resemble the young of *Hypsomyonia*. The two are quite easily distinguished, however, because the young *Aulacella* is marked medianly on the pedicle valve by two central costellae and the brachial sulcus contains a median rib, just the reverse of *H. stainbrooki*. Furthermore, young *Aulacella* is rounded and has a much narrower hinge than *Hypsomyonia*. Brachial interiors of the two are easily distinguished because *Aulacella* has only a low median ridge.

Family SCHIZOPHORIIDAE
Genus MONELASMINA Cooper, n. gen.
(Gr. monos, one; elasma, plate)
Plate 11, D, figures 30–38; text-figure 1, B, 10

Shell small, dalmanelloid in appearance, inequivalve, the pedicle valve having the greater depth; anterior commissure strongly sulcate; pedicle valve subcarinate, brachial valve deeply and narrowly sulcate. Hinge narrower than the mid-width. Surface multicostellate. Interarea moderately long; delthyrium open. Shell substance endopunctate.

Pedicle interior with moderately deep delthyrial cavity and an elongate oval muscle field; diductor scars long and slender, adductor field moderately wide; dental plates short and thick. Vascula media thick, short, sending branches anteromedially, anteriorly and posterolaterally.

Brachial interior with deep notothyrial cavity occupied by a thick, bilobed cardinal process; brachiophores moderately long, pointed but with thickening for articulation with crural fossette, supported by steep, flaring plates extending anteriorly as a ridge around the sides of the adductor field. Fulcral plates small but present. Sockets deep and with a lateral tooth. Median septum long, high, dividing the valve into two chambers. Surface of median septum facing pedicle valve marked by a deep but narrow groove.

Type species.—*Orthis deshayesi* Rigaux, 1873, Mem. Soc. Acad. Boulogne-sur-mer, vol. 20, p. 50, pl., figs. 4a-c.

Discussion.—This genus is characterized by its dalmanelloid form, elongate pedicle muscle area, the high median septum in the brachial valve and the flaring brachiophore supporting plates, long brachiophores and fulcral plates. This species has been placed frequently in *Skenidium* because of the long and high median septum but is endopunctate and does not have a cruralium or spondylium like *Skenidium*. The brachial interior of *Monelasmina* is like that of *Schizophoria* rather than *Skenidium* or any of its allies.

The identity of the brachial cardinalia to those of *Schizophoria* at once distinguishes *Monelasmina* from *Mystrophora* to which it has been mistakenly assigned, or *Kayserella* to which it has considereble exterior similarity. The genus is thus placed in the family Schizophoriidae. *Monelasmina* thus affords another interesting example of parallel development or homeomorphy, a phenomenon of considerable frequency in the punctate orthoids. It is interesting to note that the punctate genera herein described all show a parallel development of an extravagant median septum which is a feature that seems to develop along with an increasingly large shell cavity.

Types.—Figured hypotypes: USNM 61224a, b, 123349a, b.

Superfamily RHYNCHONELLACEA
Genus STEGERHYNCHUS Foerste, 1909

The name *Stegerhynchus* was first used (Foerste 1909, pp. 96–98) without benefit of generic diagnosis for a variety of *Rhynchonella whitii* Hall, called *praecursor*, and a variety of *R. neglecta* Hall, named *cliftonensis*. Foerste states (p. 98), as a result of his observations on these varieties and comparisons with other species, that *Rhynchonella whitii*, *R. neglecta* and *R. indianensis* "are congeneric." The two varieties are characterized on their interior by a cardinal process. Foerste selected no type for his genus.

In 1929 Schuchert (in Schuchert and Levene, p. 116) selected *Rhynchonella whitii* Hall as type of *Stegerhynchus*. This was first in the list of species congeneric with the new varieties named by Foerste. The few generic characters mentioned by Foerste were derived from specimens he thought were merely varieties of *R. whitii* and *R. neglecta*. In accord with this type selection the generic characters must be derived from *R. whitii* Hall which actually proves to be quite distinct from Foerste's two varieties.

Specimens of *R. whitii* and *R. neglecta* have been sectioned but none of the sectioned specimens shows a cardinal process. It is evident therefore that *Stegerhynchus* must be redefined on the basis of *R. whitii* and that Foerste's two varieties must receive another name. The generic name *Ferganella* proposed by Nikiforova in 1937 seems appropriate for Foerste's varieties.

Hall and Clarke placed *R. whitii indianensis* and *R. w. neglecta* in *Camarotoechia*. However, differences appear on the inside and outside between the two genera. Externally *R. whitii* is a somewhat compressed form with the umbo of the brachial valve marked by a median sulcus. On the inside the chamber of the brachial valve is not covered by plates growing laterally across it.

Kozlowski (1929, p. 146, 148) placed *Stegerhynchus* in the synonomy of *Stenochisma* (=*Stenoscisma*) Conrad when it was thought that *Stenoscisma* had the characters of *Rhynchonella formosa* Hall (=*Machaeraria*) and when it was believed that *Stegerhynchus* had the characters of *Rhynchonella* (*Stegerhynchus*) *whitii-praecursor*. The name *Stenoscisma* is now correctly applied only to shells congeneric with *Terebratula schlotheimi* von Buch which were formerly called *Camerophoria* and *Machaeraria* is proposed for the *Rhynchonella formosa* Hall. *Machaeraria* is not the same as *Stegerhynchus* in either the old sense or the new one because

Stegerhynchus is provided with a median septum and *Machaeraria* has none. Kozlowski's assignment of *Stegerhynchus* to that synonymy was therefore incorrect.

Genus FERGANELLA Nikiforova, 1937

Ferganella NIKIFOROVA, 1937, Central Geol. Prospect. Inst. Palaeont. U.S.S.R. Mon., vol. 35, fasc. 1, pp. 39–42, 77–78.

FERGANELLA PRAECURSOR (Foerste)

Rhynchonella (Stegerhynchus) whitii-praecursor FOERSTE, 1909, Bull. Denison Univ., vol. 14, p. 96, pl. 3, figs. 47 a–c.

In his description of this species Foerste failed to name a holotype. The writer therefore selects the internal mould (steinkern) illustrated on plate 3, fig. 47C. This specimen (USNM 87019a) preserves impressions of both valves but only the pedicle valve is illustrated. As pointed out above, Foerste's variety actually is not congeneric with *R. whitii* Hall, consequently the variety is elevated to specific rank.

FERGANELLA CLIFTONENSIS (Foerste)

Rhynchonella (Stegerhynchus) neglecta-cliftonensis FOERSTE, 1909, Denison Univ. Bull., vol. 14, p. 97, pl. 3, figs. 48 a–c.

Inasmuch as this variety has no relationship to *Rhynchonella neglecta* Hall it is elevated to specific rank. Specimen number USNM 87020a is selected as the type of the species. This specimen appears on plate 3, fig. 48 B.

Genus MACHAERARIA Cooper, n. gen.
(Gr. machaira, a saber)
Plate 13, B, figures 13–29

Shell attaining a width of about 1 inch, rhynchonelloid in appearance; inequivalve, the brachial valve having the greater depth; anterior commissure strongly uniplicate; delthyrium partially closed by disjunct deltidial plates; foramen small; surface costate.

Pedicle valve with long slender teeth having small fossettes; dental plates short, thin, bounding narrow umbonal cavities; muscle field extending anterior to the delthyrial cavity; diductor scars elongate-flabellate; adductor patch small, elongate oval.

Brachial valve with divided hinge-plate; the outer plates broad and triangular and serving as crural bases; socket-plate a low, narrow ridge bounding the socket and terminating in a small tooth which articulates with the crural fossette; sockets defined by narrow fulcral plates; sockets not corrugated; crus a long curved plate, thin and crescentic in section, the free end bluntly pointed and deeply concave toward the valve middle; crus extending posteriorly as a narrow ridge under the outer-hinge-plate and meeting the floor of the valve at the posterior to form a narrow notothyrial cavity; inner hinge-plates small, narrow, almost meeting in some specimens. Notothyrial cavity occupied by a cardinal process having a long, thin shaft and narrow, crinkled myophore. Median septum absent.

Type species.—*Rhynchonella formosa* Hall, 1857, 10th Ann. Rept. New York State Cab. Nat. Hist., p. 76.

Types.—Figured hypotypes: USNM 123399, 123400, 123401a–e.

Discussion.—This species is characterized by its gentle contours, strong costae, presence of dental plates in the pedicle valve, absence of a median septum, presence of a cardinal process and the broad, divided hinge-plate. It is thus similar to *Orthorhynchula* and *Ferganella* (see below) both of which are characterized by the presence of a cardinal process. It differs from each of these however in details of the exterior and interior.

Machaeraria is externally like *Orthorhynchula* in the contours of the valves and in the costation except for the development of the costae on the fold which is more like that of the Silurian genus *Ferganella*. The chief difference on the exterior between *Orthorhynchula* and *Machaeraria* is the presence in the first of fairly conspicuous interareas on each side of the delthyrium. Furthermore, the delthyrium is not modified by deltidial plates. The pedicle valves of both genera are provided with dental plates. Inside the brachial valves the structures are similar but those of *Orthorhynchula* have more concave outer plates on the hinge-plate and the inner plates are absent or poorly developed. The short plates supporting the hinge-plate are discrete in young shells but are situated on a callosity under the cardinal process in older specimens. The plates unite with the callosity which is joined to a moderately developed median septum.

The type specimen of Rhynchonella for-

mosa *Hall.*—No type specimen has been selected for Hall's species. The specimen selected must come from those illustrated by Hall in the 10th Annual Report. The illustrations in this report are not good: two of them (figs. 4 and 5) are outline drawings of the anterior view of a complete specimen and are rejected as unsuitable. Figure 3 is almost unrecognizable and appears not to have been used later in the third volume of the Paleontology of New York. This is not true of the remaining figures, 1 and 2. Comparison of the outlines of these pictures with the illustrations on plate 35 of volume 3 of the New York Paleontology indicates that figures 1 and 2 of the 10th Report are figures 6p and 6o, respectively, of plate 35 of volume 3 of the Paleontology. Hall and Clarke on plate 56 of volume 8 of the New York Paleontology figure the same two views (figs. 41 and 43) as those referred to in the preceding sentence but have an additional side view, figure 42, which is the same as figure 6r of volume 3. Therefore the three views in volume 3 of the Paleontology of New York, figures 6o, 6p and 6r illustrate a single specimen which is in a lot numbered 2481/3 in the American Museum of Natural History. Inasmuch as this is the best and most completely illustrated specimen of *R. formosa* Hall, it is here selected as the type of the species. It comes from the Becraft limestone at Carlisle, New York.

Genus FENESTRIROSTRA Cooper, n. gen.
(Latin fenestra, opening; rostrum, beak)
Plate 13, A, figure 1–12; text-figure 1, E, 22–37

Usually large, thick-shelled, rhynchonelloid in outline and profile; valves subequal in depth, the brachial valve having a slightly greater depth; anterior commissure strongly uniplicate; surface costellate, the costellae uneven and increasing by bifurcation and intercalation; entire surface finely filate.

Pedicle valve with minute foramen in the strongly incurved beak; delthyrium partially closed by thick deltidial plates; beak ridges strong. Delthyrial cavity deep and narrow, occupied by the pedicle; muscle field anterior to the delthyrial cavity. Dental plates short and stout.

Brachial interior with short, deep and narrow septalium supported by a long,

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EXPLANATION OF PLATE 13

A. *Fenestrirostra glacialis* (Billings) Cooper, n. gen. (p. 56)

FIGS. *1–12—1–5*, Respectively brachial, posterior, side, pedicle and anterior views of a large and nearly perfect specimen showing divided and intercalated costae, ×1, hypotype USNM 123740a; *6–10*, pedicle, brachial, side, anterior and posterior views of a smaller specimen showing coarse posterior ribbing and nearly smooth anterior part, ×1, hypotype USNM 123740b; *11*, posterior view of a mould of the interior prepared by burning and scraping shell, ×1, hypotype USNM 123740c; *12*, rubber replica of the interior showing short dental plates, small septalium and stout median septum, ×2, prepared from preceding mould of the interior.

Gun River formation, Wreck Beach, Anticosti Island.

B. *Machaeraria formosa* (Hall) Cooper, n. gen. (p. 55)

FIGS. *13–17*, Respectively anterior, pedicle, posterior, side and brachial views of a complete but somewhat exfoliated specimen, ×1, hypotype USNM 123399.

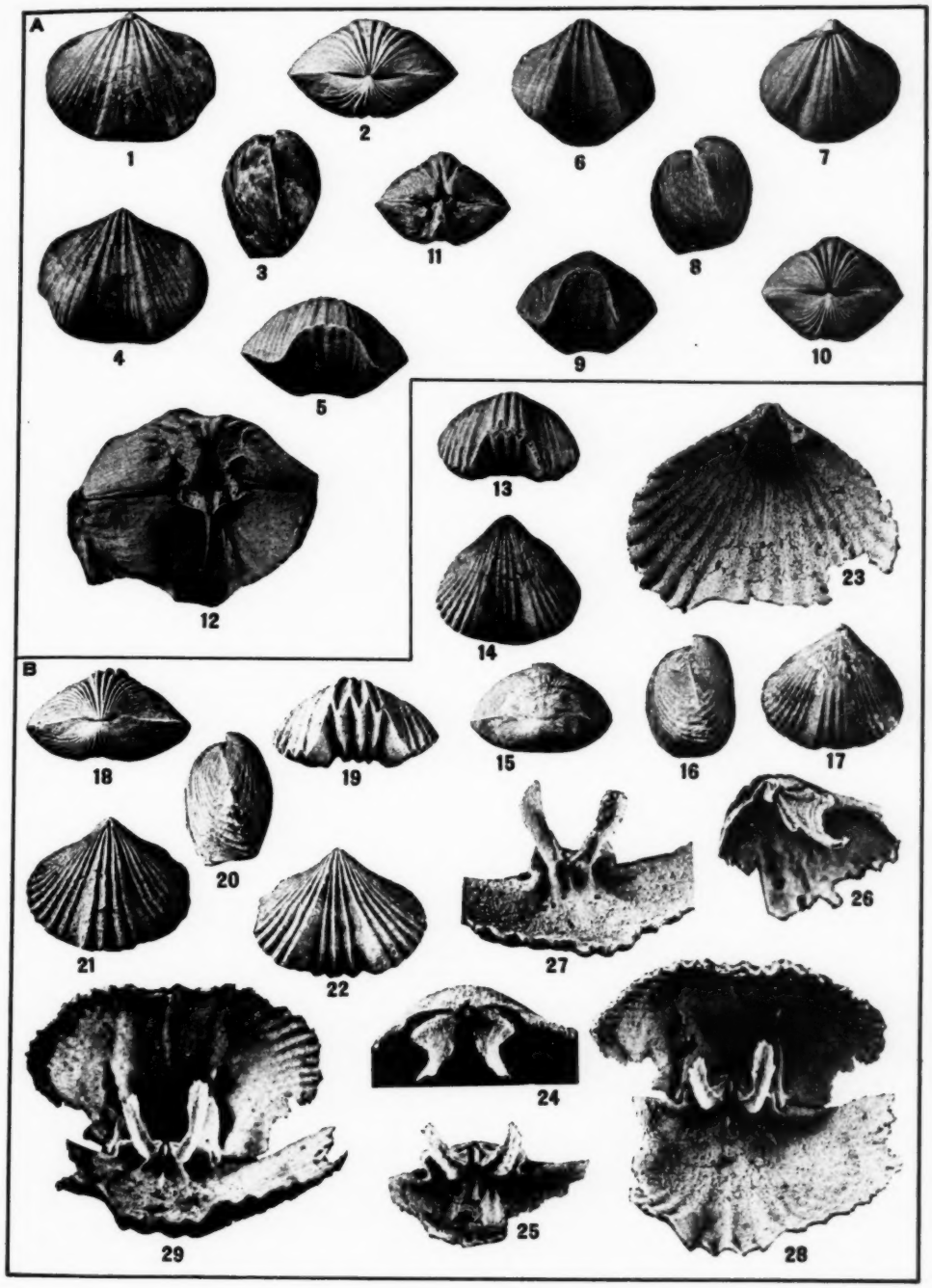
Becraft formation, Schoharie County, New York.

18–22, Posterior, anterior, side, brachial and pedicle views of a nearly perfect specimen, ×1, hypotype USNM 123400.

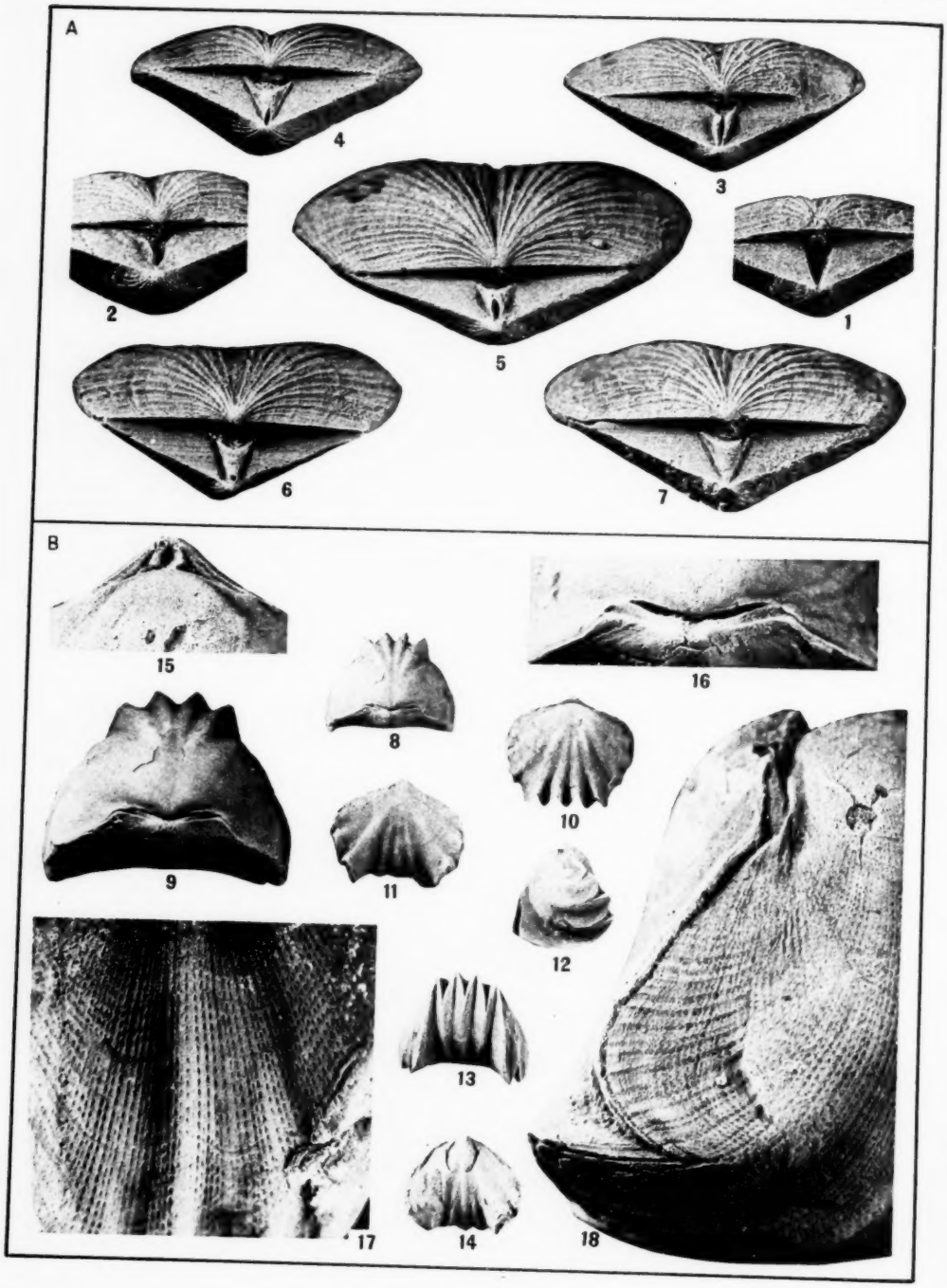
New Scotland formation, just west of Leesville on U. S. highway 20, 1½ miles northwest of Sharon Springs, New York.

23–29—23, Interior of the pedicle valve showing teeth, crural fossettes and dental plates, ×3, hypotype USNM 123401a; *24*, *25*, posterior portion of the brachial valve showing socket plates, crura, and cardinal process. Ridges along anterior surface of crural plates are visible, ×4, hypotype USNM 123401c; *26*, fragment of posterior of brachial valve seen from inside and showing socket ridge and crus, ×4, hypotype USNM 123401e; *27*, posterior part of brachial valve tilted to show crural supports, cardinal process and sockets, ×4, hypotype USNM 123401d; *28*, *29*, two views of the posterior half of a specimen with both valves united showing dental plates and cardinalia, ×4, hypotype USNM 123401b.

Becraft formation, just west of Chambers Cemetery, 3.2 miles northeast of Cobleskill, Cobleskill (7½ minute) quadrangle, New York.



Cooper, Middle Paleozoic brachiopods



Cooper, Middle Paleozoic brachiopods

stout median septum. Socket ridges thick and long, supporting long curved crura which taper distally into flat blades.

Type species.—*Rhynchonella glacialis* Billings, 1862, Palaeozoic Fossils, vol. 1, p. 143, fig. 120. Known specimens from Anticosti.

Types.—Figured hypotypes: USNM 123740a–c.

Discussion.—This genus is characterized by its peculiar ornamentation consisting of bifurcating and intercalated costellae, a feature rare in rhynchonelloids; the small pedicle foramen, the deep and narrow septalium and the long thick median septum.

The bifurcating and intercalating features of the costellae are not the only unusual characters of the exterior. The umbo of the pedicle valve is subcarinate and marked by a single prominent costella. The corresponding part of the brachial valve is marked by a fairly deeply sulcate umbo with a narrow striation between the two initial costellae. As the valve becomes more mature the sulcus is eliminated and is gradually elevated into a low fold. On the pedicle valve the reverse is true. The umbonal fold or carina becomes depressed to form a broad and shallow sulcus as usual in rhynchonelloids. The sulcus of the umbo of the brachial valve seems to be an accommodation for the strongly incurved pedicle beak which almost lies on the umbo of the brachial valve. So close is the beak to the umbo of the brachial valve that the pedicle must have occupied the umbonal sulcus as a sort of pedicle groove. The strongest part of the ornamentation is in the posterior half of the valve. Anteriorly the costellae become finer, more subdued and in some instances more distant and even obsolete. The shell is thus characterized by a gentleness of its external sculpture. This is true of the profile and outline, both of which are softly rounded.

The beak of the pedicle valve is small and sharp and is marked by an apical, often postapical foramen of small size. This opens into a narrow delthyrial chamber. The delthyrium is partially closed by thick deltidial plates.

Thick and ponderous plates characterize the interior of the brachial valve. These form a narrow, deep, but short septalium which has no cardinal process in it. The median septum reaches to about the valve middle. The crura are stout and solid tapering to thin plates but are not provided with hooks at the end.

This genus has been hitherto assigned to *Camarotoechia* but the character of the exterior ornamentation at once removes it from that genus. This is true also of some of

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EXPLANATION OF PLATE 14

A. *Phragmophora schnuri* Cooper, n. gen., n. sp. (p. 52)

FIGS. *1–3—1*, Specimen showing no trace of a notodeltidium, ×4, paratype MCZ 9405j; *2*, notodeltidium developed on one side only or possibly stripped from one side, ×4, paratype MCZ 9405h; *3*, specimen showing notodeltidium open at anterior side and enclosing a long slit-like foramen, ×4, paratype MCZ 9405i.

Middle Devonian, Gerolstein, Eifel, Germany

4, Specimen showing slit-like foramen much shortened and narrowed, ×4, paratype MCZ 9407a.

Middle Devonian, Kerpen, Eifel, Germany.

5–7—5, Foramen narrowing toward beak and notodeltidium closed in anterior part, ×4, paratype MCZ 9406a; *6*, notodeltidium nearly completely closed and foramen reduced to a minute hole, ×4, paratype MCZ 9406b; *7*, notodeltidium completely closed, and foramen sealed off, ×4, paratype MCZ 9406c.

Middle Devonian, Prüm, Eifel, Germany.

B. *Porostictia perchaensis* (Stainbrook) Cooper, n. gen. (p. 26)

FIGS. *8–18—8, 9*, Respectively ×1 and ×2 views of the posterior of a complete specimen showing the beak ridges, hypotype USNM 123395a. *10–13*, respectively brachial, pedicle, side and anterior views of the preceding, ×1; *14*, interior mould of pedicle valve showing slots of dental plates, ×1, hypotype USNM 123395c; *15* posterior of a complete specimen showing reflected deltidial plates and foramen, ×3, hypotype USNM 123394a; *16*, enlargement of the beak region of hypotype USNM 123395a showing beak ridges in detail; *17*, anterior portion of sulcus, ×4, showing rows of pits on exterior, paratype USNM 123396a; *18*, side view of another specimen, ×4, showing exterior pits, paratype USNM 123395b.

Percha formation (Box member), Wilson Ranch, sections 2 and 11, T. 18 S., R. 7 W., south of Hillsboro, Hillsboro (15 minute) Quadrangle, New Mexico.

the interior characters such as the foramen of the pedicle valve and the robust cardinalia of the brachial valve.

The character of the beak of the pedicle valve suggests relationship to *Lepidocyclus* and the nature of the ornamentation suggests *Nudirostra* (*Leiorhynchus*) which also has a minute pedicle foramen. *Lepidocyclus* differs from *Fenestrirostra* in having the deeply concave "deltidial" plates which form a pedicle tube quite unlike the structure of the Anticosti shell. Furthermore, the cardinalia of *Lepidocyclus* are characterized by a cardinal process, another unusual feature in the rhynchonellids but lacking from the Anticosti genus. *Nudirostra* is often ornamented with bifurcating and intercalating ribs similar to *Fenestrirostra* but usually the posterior half of *Nudirostra* is smooth rather than the anterior half as in *Fenestrirostra*.

Genus PEGMARHYNCHIA Cooper, n. gen.
(Gr. pegma, thickened; rhynchos, beak)

Small, trianguiar to subpentagonal in outline; pedicle valve nearly plane in profile, brachial valve gently convex, deeper than the pedicle valve. Anterior commissure narrowly uniplicate. Foramen triangular; deltidial plates incipient or lacking. Surface completely costate.

Pedicle interior with ponderous, corrugated teeth attached to the sides of the delthyrial cavity and not supported by dental plates. Muscle field large, flabellate, occupying most of the inner surface; diductor scars large and flabellate, adductor field long and narrow.

Brachial interior with ponderous cardinal process consisting of narrowly divergent, strongly elevated socket plates thickened on their inner surface and welded together medially to form a broad thick plate often elevated medially into a rounded boss; apex under beak a deep muscle pit. Sockets deep, transversely corrugated. Crura moderately long, broadly crescentic in section and with concave face directed inward, attached on the inside of the socket plates. Median ridge nearly obsolete to slightly elevated.

Type species.—Pegmarhynchia zimmi Cooper, n. sp.

Discussion.—The generic features of this interesting little genus appear in the wholly plicate shell, the corrugated, unsupported teeth, enormous muscle field in the pedicle valve and the peculiar structure of the cardinalia. In these characters the genus differs from *Eatonia* to which these shells had hitherto been assigned, and from *Costellirostra* which was recently separated from *Eatonia*.

The ornamentation of *Eatonia* is not unlike that of *Pegmarhynchia* but generally differs, at least in some species, in having a number of intercalated or bifurcated costae, and *Eatonia* is generally a more transverse shell than *Pegmarhynchia*. The interior of the pedicle valve of *Eatonia* is quite unlike that of *Pegmarhynchia* in having small teeth which in young specimens are supported by short, obscure dental plates. Furthermore, the muscle field of *Eatonia* is quite unlike that of *Pegmarhynchia* in being shorter and rounder and in being enclosed by a prominent thickened rim. The adductor field of *Eatonia* is short, deeply depressed and the scars are divided by a thin median septum confined to the adductor field. This septum terminates in a chamber in the anterior end of a low ridge that extends from the delthyrial cavity. This adductor chamber is extravagantly developed in some specimens but nothing like it has been seen in *Pegmarhynchia*.

The brachial interiors of *Eatonia* and *Pegmarhynchia* are also quite unlike. The cardinal process of *Eatonia* is an elevated boss inside the socket plates bearing on its posterior end two deep myophore pits; the socket plates are divergent and define two deep sockets. In old specimens the teeth contain a longitudinal ridge bounded by two troughs and the sockets bear a corresponding trough and bounding ridges. These are in strong contrast to the corrugated teeth and sockets of *Pegmarhynchia*. The crura are stout at the base and with rounded cross-section in *Eatonia*. Distally they become narrow and flattened and the tips are expanded into a plate transverse to the axis of the crus. These contrast with the short crescentic plates of *Pegmarhynchia*. In addition to these details the median septum of *Eatonia* is more prominent than that of *Pegmarhynchia* and is strongly thickened posteriorly.

Costellirostra as its name implies differs

strongly from *Pegmarhynchia* in the details of the exterior ornamentation. The differences between the interior of the two genera is as striking as that between *Pegmarhynchia* and *Eatonia* because the latter and *Costellirostra* are quite similar. The interiors of the pedicle valves of *Costellirostra* and *Eatonia* are so similar that the comparison of the pedicle interior of *Pegmarhynchia* with *Costellirostra* need not be recited.

Inside the brachial valve of *Costellirostra* the median septum and cardinal process are similar to those of *Eatonia* but are much more elaborately developed. The cardinal process swells up between the socket plates and protrudes for some distance into the delthyrial cavity. The myophore faces directly toward the pedicle valve rather than posteriorly as it does in *Eatonia* and forms two lobes. The crura are short, rounded in section and are given off just inside the socket plates.

Besides the type species, *Eatonia whitfieldi* Hall from the Oriskany formation of Maryland is placed in *Pegmarhynchia*.

PEGMARHYNCHIA ZIMMI Cooper, n. sp.
Plate 12, C, figures 27–37

Shell small, subtriangular to subpentagonal in outline, with nearly flat pedicle valve and moderately convex brachial valve. Pedicle valve provided with a moderately deep sulcus originating about 5 millimeters anterior to the beak. Sulcus occupied by a strong median costa extending to anterior margin; costa on each side of the median one but not always reaching the margin. Pedicle anterior tongue short, narrow, bent almost at right angles to commissure. Flanks bounding sulcus marked by seven costae the outer two obscure.

Brachial valve gently convex in lateral profile with a narrow fold defined only at the front third or quarter. Base of fold near its place of origin marked by four costae but where elevated it is marked by two costae only, the lateral ones failing to develop. Flanks convex, depressed below level of fold; lateral slopes steep.

Interior as defined for the genus.

Types.—Holotype: USNM 108208a; paratypes: USNM 108208b, d, e; unfigured paratype: USNM 108208c.

Horizon and locality.—Glenerie limestone, east side of U. S. highway 9 W, at Glenerie, New York. The species is named for Mr. Bruno L. Zimm.

Discussion.—Resembles *Pegmarhynchia whitfieldi* first described from Maryland but differs in its larger size, less acuminate beak, and more prominent fold and sulcus.

Genus HYBORHYNCHELLA Cooper, n. gen.
(Gr. hybos, humpbacked; rhynchos, beak)

Thick-shelled, small, inequivalved, the pedicle valve strongly swollen and the brachial valve nearly plane to moderately concave in lateral profile; anterior commissure narrowly uniplicate, pedicle tongue long; delthyrium large, usually plugged by the brachial umbo; interarea a remanent or absent; foramen slightly posterior to the apex, small. Beak ridges short, obscure. Surface costate, the costae strongest in the anterior half.

Pedicle interior with thick and ponderous teeth; dental plates absent; delthyrial cavity deep; muscle field small; adductor track wide; vascula media strong, narrow and divergent.

Brachial interior with short, shallow, narrow cruralium and flattened hinge-plate with long, prominent socket plates and long, curved slender crura, all supported by a prominent but slender median septum extending almost to the middle of the valve.

Type species.—*Hyborhynchella bransoni* Cooper, n. sp.

Discussion.—*Hyborhynchella* is characterized by its peculiar exterior which combines a moderately concave brachial valve with a narrowly uniplicate commissure and a strongly swollen to bulbous pedicle valve. The interior of the brachial valve is like that of *Nudirostra* (formerly *Leiorhynchus*, text-fig. 1, D) and the related genera *Pseudocamerophoria* Wedekind, *Caryorhynchus* Crickmay, *Basilicorhynchus* Crickmay, and *Calvinaria* Stainbrook. Besides the interior features *Hyborhynchella* shares with the above genera several important characters: small foramen but large delthyrium usually blocked by the umbo of the brachial valve, a more or less nude beak, irregular costation, often thick shell in the umbonal regions and uniplicate commissure. It differs from all the above genera in the concavity of the brachial valve and in minor details of the interior.

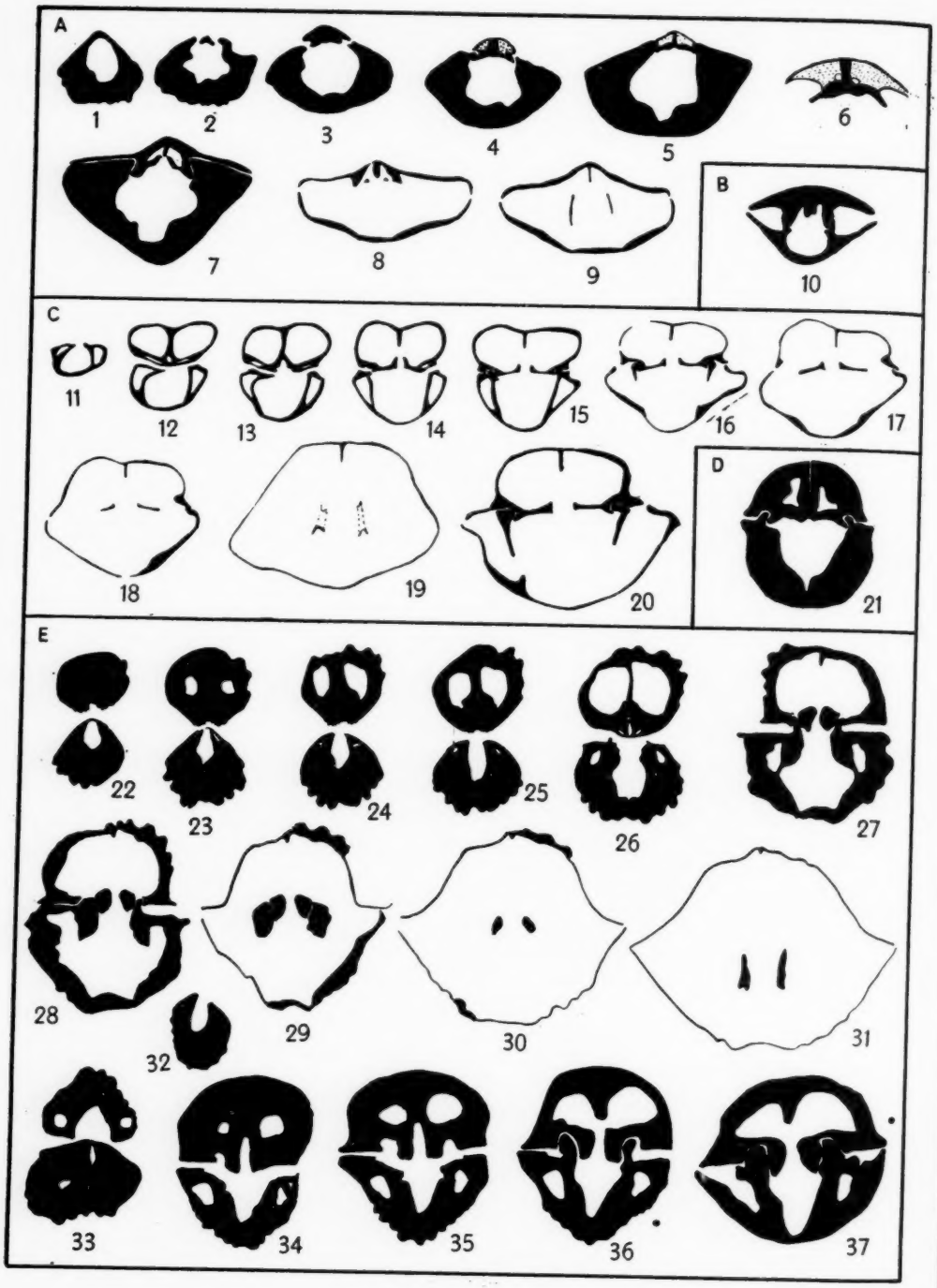

FIG. 1—Serial sections.

Other known nudirostrid genera are biconvex but the valves are more nearly of equal depth than those of *Hyborhynchella*.

The pedicle interior of *Hyborhynchella* differs from that of *Nudirostra* in having the muscle field located more posteriorly and not separated from the beak by a shell thickening. The beak characters of the two genera however are quite similar. *Hyborhynchella* has a strong set of vascula media that extend into the muscle field and are strongly divergent anteriorly. Such a pair of vascula media were not observed in *Nudirostra* or the other related genera.

The brachial interior of *Hyborhynchella* does not differ markedly from other nudirostrids. In these genera, as in *Hyborhynchella*, the socket-plates and crural bases are welded together to make a short, flattened hinge-plate. The cruralium is small and short and may be nearly obsolete in old shells. The median septum of *Nudirostra*

EXPLANATION OF TEXT-FIG. *1*

A. *Hyborhynchella bransoni* Cooper, n. gen., n. sp. (p. 62)

FIGS. *1–9—1*, Section 0.35 mm. anterior to beak. Note lack of dental plates; *2*, 0.5 mm. anterior to beak, showing first appearance of brachial valve; *3*, 0.65 mm. from beak, showing appearance of hinge-plate. Cavities under hinge-plate are filled by shell deposit; *4*, 0.8 mm. anterior to beak, showing median septum and hinge-plate. Stippled area represents adventitious shell deposit; *5*, about 1.0 mm. anterior to beak, showing thinning of median septum; *6*, brachial valve of preceding in more detail, showing the beginning of the cavities under the hinge-plate, ×6; *7*, about 1.15 mm. anterior to the beak, showing the end of the hinge-plate. All about ×3. *8*, *9*, two sections of another specimen anterior to the hinge-plate, showing the origin of the crura and the slender crura. The sections are 0.16 mm. apart.

Sly Gap formation, Indian Wells Canyon, 3 miles east of the north side of Alamogordo, Sacramento Mountains, New Mexico.

B. *Monelasmina deshayesi* (Rigaux) Cooper, n. gen. (p. 53)

FIG. *10*, Section about 1.5 mm. anterior to the beak showing thick cardinal process and brachiophore supporting plates. The pedicle valve is down, about ×3.

Frasnian, Beaulieu, Boulonnais, France.

C. *Porostictia perchaensis* (Stainbrook) Cooper, n. gen. (p. 62)

FIGS. *11–20—11*, Section 0.8 mm. anterior to the tip of the beak, showing dental plates; *12*, 1.5 mm. anterior to beak, showing beginning of septalium, septum and sockets; *13*, 2.2 mm. anterior to beak, showing septalium and dental plates; *14*, 2.6 mm. anterior to beak, showing septum split off from septalium and hinge-plate beginning to divide; *15*, 2.8 mm. anterior to beak, hinge-plate divided, teeth in sockets, septum becoming lower; *16*, 3.0 mm. anterior to beak, showing hinge-plate passing into crural bases; *17*, 3.2 mm. anterior to beak, crural bases becoming slender; *18*, 3.4 mm. anterior to beak, same as above; *19*, 3.7 mm. anterior to beak, showing curved crura lying nearly parallel to the plane of the section. All sections slightly greater than ×2. *20*, Section taken at place of shell articulation about 2.5 mm. from beak of another specimen showing hinge-plate divided and dental plates disappearing. About ×3.5.

Percha formation (Box member), Wilson Ranch, south of Hillsboro, Hillsboro (15 minute) Quadrangle, New Mexico.

D. *Nudirostra* sp. (p. 59)

FIG. *21*, Section taken at place of articulation. Compare with sections of *Hyborhynchella*. ×2.5. Figured specimen USNM 123741.

Oñate formation, Alamo Peak, Sacramento Mountains, New Mexico.

E. *Fenestrirostra glacialis* (Billings) Cooper, n. gen. (p. 56)

FIGS. *22–37—22*, Section 2.5 mm. anterior to crest of umbo; *23*, 3.0 mm. anterior to crest of umbo, showing beginning of umbonal chambers in both valves; *24*, *25*, 3.6 mm. from crest of umbo, showing enlarging umbonal chambers; *26*, 3.7 mm. from crest of umbo, showing beginning of septalium and sockets in brachial valve and beginning of dental plates in pedicle valve; *27*, 3.9 mm., septalium already breached and short septum much reduced; *28*, 4.2 mm., dental plates disappearing and crural bases thick; *29*, 4.3 mm., dental ridges remaining, crural bases narrowing; *30*, *31*, 4.9 mm., long slender crura. All sections about ×2. *32–37*, Another series of sections showing similar development of structures to that above, all about ×2.

Gun River formation, Wreck Beach, Anticosti Island, Canada.

sensu stricto, is usually much thickened but that of *Hyborhynchella*, even in the thickest-shelled specimens is a slender plate.

HYBORHYNCHELLA BRANSONI Cooper, n. sp.
Plate 12, A, figures 1–11; text-figure 1, A, 1–9

Small, thick-shelled, inequivalve, the pedicle valve strongly convex and deep. the brachial valve shallow and gently concave; hinge narrow; anterior commissure strongly uniplicate; sides narrowly rounded; surface paucicostate.

Pedicle valve strongly convex and inflated in lateral profile; strongly domed in anterior profile but with the crest of the dome gently concave and the sides steep. Umbo strongly convex; beak small and resorbed by pedicle pressure to form a notched foramen; sulcus originating on the umbo and extending to the anterior margin, shallow, occupied by one to three costae. Tongue short, truncated. Flanks bounding sulcus narrowly elevated at the sulcus margin but descending steeply and flatly to the lateral margins. Delthyrium open, interareas small. Interior with small teeth and deep delthyrial cavity. Dental plates absent; muscle field small, deeply impressed in the thick shell, individual scars obscure.

Brachial valve concave in anterior and lateral profiles; umbo gently and narrowly convex, the convexity continued anteriorly to the front margin as a narrow, fairly strongly elevated fold having two or three costae at the front. Regions bounding fold forming moderately deep troughs to the anterolateral margin; flanks flat in profile, descending steeply to the troughs bounding the fold. Brachial interior with short, undivided hinge-plate having sharply defined socket ridges, crura long and slender. Hinge-plate supported by an elevated median septum that extends to about the valve middle. Measurements in millimeters:

	Length	*Brachial length*	*Mid-width*	*Hinge width*	*Thickness*
Holotype	6.9	6.0	8.0	1.4	3.9
Paratype 123344b	7.2	6.3	8.2	2.2	4.4
Paratype 123344c	8.4	6.9	10.0	3.2	5.2

Types.—Holotype USNM 123344b; figured paratypes USNM 123343a, c, 123344a-c; unfigured paratypes USNM 123343 b, d–f, 123344d–j.

Horizon and locality.—Sly Gap formation in Indian Wells and Marble Canyons, 3 miles east of Alamogordo, Sacramento Mountains, New Mexico.

Discussion.—No other species of this genus is known to which this one may be compared. *Hyborhynchella* may be confused with *Gypidula* or *Pentamerella*, both of which it resembles. It differs from the former in having a sulcate pedicle valve and from the latter in having a concave brachial valve. Absence of a spondylium in *Hyborhynchella* is a sure distinction from *Gypidula* or *Pentamerella*.

Genus POROSTICTIA Cooper, n. gen.
Plate 14, B, figures 8–18; text-figure 1, C, 11–20
(Gr. poros, pore; stictos, in a row)

Shell rhynchonelliform, thin, somewhat rectangular in outline; anterior commissure strongly uniplicate; brachial valve much deeper than the pedicle valve; ornamentation paucicostate and entire valve covered by fine radial lines separated by rows of fine pits.

Pedicle valve with incurved, suberect beak; deltidial plates disjunct (?) or anteriorly united, small; foramen large. Beak ridges angular, long and defining a narrow interarea. Interior with short, widely divergent dental lamellae. Muscle field moderately long, oval, surrounded laterally and partially anteriorly by a low thickening extending from the anterior ends of the dental plates. Pedicle scar occupying deep delthyrial cavity; muscle field anterior to delthyrial cavity.

Brachial valve with divided hinge-plate, the outer plates broad and slender; crura moderately long and curved; socket plate elevated, long, defining a long slender socket; septalium small and short; median septum long and slender. Adductor field too lightly impressed to leave distinct marks.

Type species.—*Paraphorhynchus perchaensis* Stainbrook, 1947, Jour. Paleontology, vol. 21, p. 316, pl. 47, figs. 6–8 (not 9–13)

Types.—Figured hypotypes USNM 123394a, 123395a–c, 123396a.

Discussion.—This genus is characterized

by its paucicostate exterior superimposed on which are fine radial lines with rows of fine pits in the striations between them. The interior is characterized by a small septalium, broad, triangular outer plates and a long median septum. Although this species was originally assigned to *Paraphorhynchus* its interior and exterior features are more suggestive of *Shumardella*. *Porostictia* differs from *Paraphorhynchus* in ornamentation, that of the latter genus having broad costae but the entire shell is costate. Furthermore, no rows of pits are known in *Paraphorhynchus*. Inside the pedicle valve of *Paraphorhynchus* the dental plates are long and gently convergent on their suture with the valve rather than divergent as in *Porostictia*. Inside the brachial valve the structures have a similar pattern but the outer plates of the Percha genus are broad and flat whereas those of *Paraphorhynchus* are narrow and somewhat concave.

Shumardella is very similar to *Porostictia* externally but may be distinguished by its softer contours of outline and ornamentation. *Shumardella* is more rounded in all aspects and the costae are generally less angular, less numerous and less strong. Furthermore, *Shumardella* is not covered by a fine radial or pitted ornamentation. Inside the brachial valve the structures are very similar but the outer plates of the hinge-plate are longer and flatter in *Porostictia* than in *Shumardella*.

Porostictia is fairly common in the Percha shale (Box member) near Silver City, Kingston, and south of Hillsboro, New Mexico.

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NEW BRACHIOPODS FROM CUBA

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ABSTRACT—A new genus, *Orthothyris*, belonging to the Cancellothyrinae and coming from Cretaceous rocks of Habana Province is a lateral offshoot from *Terebratulina* or *Disculina*. A second new genus *Phragmothyris* is described. This proves to be a forerunner of the modern West Indian genus *Argyrotheca*. The Eocene *Phragmothyris* is unlike modern *Argyrotheca* in having a deltidial cover and strong muscle platforms. *Orthothyris* is represented by the type species only, *O. radiata*, n. sp., while five new species of *Phragmothyris* are described: *P. costellata*, *P. cubensis*, *P. palmeri*, *P. rotunda* and *P. subplana*.

THE brachiopods described and figured herein were presented to the U. S. National Museum by Dr. Robert H. Palmer (Acc. 182551). The collection presented is not a large one but it represents the accumulation of a life-time of collecting in the Mesozoic and Tertiary rocks of Cuba. I gathered from Dr. Palmer during a visit to the Museum some years ago that brachiopods are not common in the early Tertiary of Cuba, or indeed, in most of the Tertiary and Cretaceous. The specimens described herein are rare forms but they add considerably to our knowledge of the subfamilies Megathirinae and Cancellothyrinae. The enormous and corroded foramen of *Argyrotheca* and its allies of the Megathirinae has been a puzzling structure but the Cuban specimens show the foramen to have originally been constricted by a prominent symphytium. The member of the Cancellothyrinae herein described is clearly an aberrant form, a lateral off-shoot of the tribe.

SYSTEMATIC DESCRIPTIONS

Superfamily TEREBRATULACEA
Family TEREBRATULIDAE
Subfamily CANCELLOTHYRINAE

Genus ORTHOTHYRIS Cooper, n. gen.

Shell small, having the appearance of an orthid and with a wide, straight hinge; elongate oval in outline; anterior commissure broadly sulcate; profile slightly biconvex to markedly concavo-convex; surface distantly costate. Shell substance punctate.

Pedicle valve deeper than the brachial valve; beak ridges strong and sharp; interarea long and broad, concave; foramen small, margined by thickened, elevated deltidial plates; musculature unknown.

Brachial valve with deep sockets defined by erect socket plates welded to a broad thickening, sulcate in the middle, that protrudes slightly from the hinge and served as a cardinal process; loop attached to anterior base of socket plate. Loop short, somewhat obliquely placed and extending toward the pedicle valve, probably like *Terebratulina*. Anterior margin scalloped as in *Orthis*.

Type species.—*Orthothyris radiata* Cooper, n. sp.

Discussion.—This genus is characterized by its form and ornamentation which are like that of the genus *Orthambonites* of the Ordovician Period; the nature of the pedicle opening which is wide and modified only by elevated plates on its sides; the wide hinge and the interior. The genus has relationships to *Terebratulina* in the form of the hinge and the brachial interior but significant differences may be noted. *Orthothyris* is also different from all other genera now placed in the subfamily Cancellothyrinae.

Orthothyris differs from *Terebratulina* exteriorly in having the brachial valve convex only just anterior to the umbo and in having strong undivided costae. In the beak region of the pedicle valve *Terebratulina* has remnantal deltidial plates located at the lower angles of the delthyrium but *Orthothyris* has the delthyrium margined by narrowly triangular plates along the delthyrial edge. These plates are fairly strongly elevated anteriorly but descend toward the apex. Unlike *Terebratulina* the delthyrium is bounded by a wide interarea which is margined laterally by sharply angular and prominent beak ridges. The apex appears to be thickened as it is in *Terebratulina*.

Inside the brachial valve the cardinal

process is wide, short and sulcate in the middle and lies between the small, narrow socket plates which are like those of *Terebratulina*. The bases of the loop arise abruptly at the base of the socket ridge and indicate that the loop extended toward the pedicle valve rather than anteriorly. The writer prepared several specimens but was unable to produce a complete loop. The brachial structures are so like those of *Terebratulina* that it is probable that the loop too, was like that of *Terebratulina*.

Although *Orthothyris* has the form of several other genera of the Cancellothyrinae it is unlike any of them. The wide hinge is suggestive of *Chlidonophora* but the beak region and ornamentation are totally unlike. *Eucalathis* is fairly strongly costate but the umbonal region of the brachial valve of *Orthothyris* is different and that valve of *Eucalathis* is uniformly convex. *Murravia* is suggestive but it is not so wide hinged and is finely constellate. Inside the brachial valve the socket-ridges are closely crowded and thick rather than widely separated and slender as in *Orthothyris*. The beak region of the pedicle valve is likewise quite different, that of *Murravia* being more like *Terebratulina* in having discrete and thick deltidial plates located at the lateral angles of the delthyrium. *Orthothyris* differs from *Rhynchonellopsis* Vincent, a Belgian terebratulinoid, in having a strongly costate ornamentation and a wide hinge.

ORTHOTHYRIS RADIATA Cooper, n. sp.
Plate 15, C, figures 16–20

Shell small, elongate oval in outline and with the widest part at about the middle; hinge narrower than the maximum shell-width, sides gently rounded; anterior margin narrowly rounded; surface costate.

Pedicle valve moderately convex in lateral profile and with the maximum curvature just posterior to the middle; anterior profile strongly and narrowly convex and with steep lateral slopes. Surface marked by strong, narrowly rounded costae separated by broad shallow grooves. Costae numbering 16 to 18. Beak strongly incurved; umbo narrowly convex, the convexity continued anteriorly and strongly to the valve middle, then lessening anteriorly, but nevertheless, forming a poorly defined fold.

Brachial valve with smooth, swollen umbo forming point from which costae radiate: lateral profile uneven, somewhat narrowly convex in the posterior fifth but moderately concave anteriorly; anterior profile broadly and gently concave. Posterolateral extremities flattened and marked by about five costellae radiating from the umbo; remainder of valve marked by strong distant costae, thus dividing the valve into two costellate sectors and a costate part, the latter occupying most of the valve. Place of division between two costellate sectors marked by oblique narrowly rounded but low fold. Median region anterior to the umbo gently concave to form a broad and shallow sulcus that extends to the anterior margin; flanks slightly convex and bent in the direction of the brachial valve.

Measurements in millimeters:

	Length	*Brachial length*	*Mid-width*	*Hinge width*	*Thickness*
Holotype	4.0	3.4	3.5	2.7	1.8

Types.—Holotype: USNM 108687; unfigured paratypes: USNM 108687a–r.

Horizon and locality.—Upper Cretaceous in Cuba, 1 mile west of Central San Antonio, Habana Province, Cuba.

Discussion.—No other species of this genus is known to which this one may be compared.

Superfamily TEREBRATELLACEA
Subfamily MEGATHIRINAE
Genus PHRAGMOTHYRIS Cooper, n. gen.

Shell small, attaining a width of slightly more than a half inch; outline and profile variable, valves moderately to strongly convex, the pedicle valve always the deeper of the two; anterior commissure rectimarginate to broadly sulcate; surface multicostellate. Shell substance coarsely punctate.

Pedicle valve often misshapen and with a large submegathyrid foramen; symphytium rarely complete, usually resorbed and reduced to vestiges or not developed. Teeth large, not supported by dental plates; interarea narrow; median ridge extending from beak nearly to front margin. Pedicle collar short.

Brachial valve with wide and deep sockets bounded by strong, elevated socket-ridges; adductor muscles situated on a thick,

elevated muscle platform; median septum extending from beak to anterior margin, strongly elevated and bisecting the shell cavity. Median septum elevated above floor of muscle platform. Loop a broad ribbon extending from the socket-ridges around the outside of the muscle platform and uniting with the floor of the valve under the muscle platform.

Type species.—Phragmothyris cubensis Cooper, n. sp.

Discussion.—Phragmothyris has obvious similarities to modern *Argyrotheca* in its opposite folding, median septa in both valves, and the type of loop in the brachial valve. Differences appear in the lack of a supported pedicle collar or shelf in the pedicle valve, the median ridge or septum of the pedicle valve extending from apex nearly to the anterior margin, the loop of the brachial valve lacking the medially directed loop extensions at the posterior, the attachment of the loop to the septum at the base of the adductor callosity or platform and the presence of thick aductor platforms. The most significant difference, however, is the presence of a deltidial cover, probably a symphytium.

Inside the pedicle valve of most Recent *Argyrotheca* the apex is marked by a nearly flat or concave plate with concave to pointed anterior margin. The plate is generally supported by a narrow and elevated median septum that extends to the valve middle. In all of the specimens of *Phragmothyris* examined this plate was not present or had been completely eroded away by the close attachment habit of these shells. The median septum of *Phragmothyris* is less conspicuous than that of *Argyrotheca* and generally is only strongly developed in the posterior part on the diductor muscle callosity or platform. Anterior to this point the elevation is not a septum but a low, often broad ridge, as illustrated by the pedicle valve of *P. cubensis*, plate 15, H, fig. 54. The diductor platform extends anteriorly to a position about under the teeth. This thickening is considerable in *P. cubensis* but is not greatly developed in the other species.

The cover over the delthyrium is a feature unknown in any *Argyrotheca*, Recent or fossil. It is exhibited by only two specimens in the collection studied. In *P. palmeri* which shows it in its most complete state, the plate is nearly flat on the sides but rises as a low arch highest at the middle. The foramen and the posterior edge of the cover are irregular and worn by pressure against the surface of attachment. The true nature of the foramen is thus unknown. The cover on the holotype of *P. cubensis* is a remnant only but it shows that this species must have had a calcified cover. In this species too the edge of the deltidial cover is worn and irregular as is the posterior margin of the foramen. It is my belief that these covers were preserved by accidents of life. In the instance of *P. palmeri* the animal lived in such a way that only the apex of the shell was brought tightly against the place of attachment. In *P. cubensis*, on the other hand, the surface on which the individual was attached was sufficiently large to rub away or prevent the growth of most of the deltidial plate as well as part of the posterior margin. It is believed that most of the other specimens would have had covers if by accident the attachment surface through life had not been a broad surface that wore most of the beak, including the deltidial cover, completely away. In some specimens of *P. rotunda* wear at the beak went so far that even part of the brachial umbo was abraded. The wear at the beak started so early in life that the deltidial covers of the few immature specimens in the collection were likewise worn off. The cover of *P. palmeri* extends from the foramen almost to the brachial valve and leaves only a small slit-like portion of delthyrium uncovered. This is a great contrast to Recent *Argyrotheca* in which the posterior part of the delthyrium is partially closed by the delthyrial plate and by disjunct and fragmentary deltidial plates. Some Recent specimens show small lateral plates along the delthyrial edge and at an angle to the interarea.

The interior of the brachial valve is essentially like that of *Argyrotheca* but differs importantly in some respects. The median septum and adductor platform are exceedingly variable. Like *Argyrotheca* the median ridge rises to a crest and is often serrrated on its anterior edge but the septum of *Phragmothyris* is much more robust and is often thickened or expanded into a shovel- or spoon-shaped plate (see pl. 15,

D, figs. 21–23). Such a thickening is rare in the modern *Argyrotheca* but can be seen in some specimens of *A. lutea* Dall. In *Phragmothyris* the maximum thickening occupies nearly the posterior half. Two pairs of muscle scars are visible, one in the posterolateral side of the callosity and the other on the anteromedian side. When the callosity is viewed from the anterior, as in the case of *P. rotunda* in which the thickening is great, large punctae are visible on the anterior face, punctae that are much larger than the normal punctae of the shell.

The socket ridges of the brachial valve are generally somewhat more conspicuous than those of Recent *Argyrotheca*. The loop is short and makes a narrow curve laterally from the base of the socket ridge to which it is united by a short crus, to join the floor of the valve at the anterior base of the adductor callosity. In the Recent pauciplicate *Argyrotheca* the loop makes a broader curve and unites with the floor and the septum near the anterior margin. In Recent *Argyrotheca* a process of the loop extends medially as a sharp point or crural process. Preparations of *Phragmothyris* do not exhibit this process but do show an extension of the loop anteriorly and toward the pedicle valve. This feature can be seen in *P. subplana* and *P. costellata*.

The exterior of *Phragmothyris* is quite different from that of the type species of *Argyrotheca*, *A. cuneata*, the folding of which is paucicostate opposite. That of *Phragmothyris* is multicostellate opposite. It is an interesting fact that the costellation is opposite even in the most finely marked of the species. Two Recent West Indian species are like *Phragmothyris* in ornamentation and may be referable to that genus: *A. lutea* Dall and *A. barrettiana* Davidson.

PHRAGMOTHYRIS COSTELLATA
Cooper, n. sp.
Plate 15, B, figures 7–15;
D, figures 21–23

Shell of medium size for the genus, wider than long; subrectangular in outline; hinge narrower than the greatest width which is at or near the middle; cardinal extremities rounded; sides and anterior margin broadly rounded; anterior commissure gently sulcate. Surface costellate; costellae narrowly rounded, separated by striae slightly narrower than the costellae and numbering about 40.

Pedicle valve gently convex in lateral profile but moderately and narrowly convex in anterior profile; umbo worn away; median region swollen; anterior region convex and with a slight suggestion of a fold at the anterior margin; flanks rounded and steep. Interarea short, mostly worn away.

Brachial valve fairly strongly convex in lateral profile and with the maximum convexity at about the middle; anterior profile broadly and strongly convex; umbo swollen; sulcus narrow and shallow, originating just anterior to the umbo; flanks swollen and with moderately long steep slopes. Interior with thickened muscle platforms and often expanded median septum.

Measurements in millimeters:

	Length	*Brachial length*	*Mid-width*	*Hinge width*	*Thickness*
Holotype	9.4	8.7	10.6	8.0	7.6

Types.—Holotype: USNM 561502a; figured paratypes: USNM 561502b, c; 561507; unfigured paratypes: USNM 561502d, f; 561503.

Horizon and locality.—Eocene in Cuba (1102) 4.65 kilometers west of Guanajay on the road to Mariel, Pinar del Rio Province; Cojimar formation (976), 1.5 to 2.5 kilometers west of Cojimar on the carretera to Casa Blanca, Habana Province.

Discussion.—This species is characterized by its small size, fine, sharp costellae, apsacline interarea, and the less elevated median septum. The species is most like *P. rotunda* but it is smaller and has sharper, more elevated costellae. Furthermore, the median septum of *P. rotunda* is more erect and the crest is turned posteriorly. In *P. costellata*, on the other hand, the crest of the septum is not so strongly elevated and is not curved in a posterior direction (compare pl. 15, D, fig. 23 with E, fig. 30).

PHRAGMOTHYRIS CUBENSIS
Cooper, n. sp.
Plate 15, H, figures 47–56

Shell large for the genus, length and width nearly equal; subtriangular in outline;

maximum width in the anterior half; sides oblique outward; anterolateral extremities narrowly rounded; anterior margin broadly rounded; anterior commissure rectimarginate; surface marked by irregular crowded costellae, broad and flattened, often curved; eight costellae in 5 mm. at the front margin.

Pedicle valve moderately convex in lateral profile, broadly and moderately convex in anterior profile. Umbonal region worn away; median region swollen, marked by a shallow and indistinct sulcus; flanks convex and steep. Symphytium a remnant; interarea short and orthocline.

Brachial valve unevenly convex in lateral profile and with the anterior and posterior flattened but the median region moderately convex; anterior profile broadly convex; umbo flattened; median region swollen; anterior somewhat flattened; flanks with long and gentle slopes.

Measurements in millimeters:

	Length	*Brachial length*	*Mid-width*	*Hinge width*	*Thickness*	*Maximum width*
Holotype	15.8	11.4	14.0	8.7	7.7	14.4

Types.—Holotype: USNM 561504a; figured paratypes: USNM 561504b, c.

Horizon and locality.—Eocene in Cuba in a deep cut north of Grua 9, Ramal Juan Criollo, Camaguey Province, Cuba.

Discussion.—This species is distinctive because of its elongated and erect beak, the delthyrium partially covered by a symphytium, the sharp costellae, the flattened brachial umbonal region, and the compressed form. The species is ornamented somewhat like *P. rotunda* but differs in having a shallower brachial valve, a flattened umbo on the brachial valve, and an elongated, erct beak. It differs from *P. costellata* in the same characters. It is larger, has a more erect beak and finer ornamentation than any of the other species described herein.

Phragmothyris palmeri
Cooper, n. sp.
Plate 15, F, figures 33–38

Shell of about medium size for the genus, wider than long; hemiconical; cardinal extremities slightly obtuse; sides nearly straight; anterior margin broadly rounded; anterior commissure rectimarginate; surface marked by distant costellae that increase by implantation, six costellae meeting the beak of the brachial valve, the others intercalated to produce 22 to 25 along the margin.

Pedicle valve hemiconical in outline, gently convex in lateral profile and narrowly convex in anterior profile; umbo resorbed, foramen large and irregular; median sulcus narrow and shallow extending for the full length of the valve; flanks bounding sulcus narrowly rounded and with steep slopes. Interarea long, apsacline; symphytium long, wide, and gently convex.

Brachial valve gently convex in lateral and anterior profiles; umbo gently swollen; median sulcus narrow and shallow, disappearing at about the valve middle where two costellae are intercalated. Flanks very gently convex.

Measurements in millimeters:

	Length	*Brachial length*	*Mid-width*	*Hinge width*	*Thickness*
Holotype	7.3	5.6	8.2	7.9	6.9

Type.—Holotype: USNM 561506.

Horizon and locality.—Eocene in Cuba in a deep cut north of Grua 9, Ramal Juan Criollo, Camaguey Province, Cuba.

Discussion.—This species is unlike any other described in this paper in having the delthyrium completely covered by a long and prominent symphytium. The brachial valve is gently convex and ornamented by somewhat distant costellae rather than closely crowded ones as in *P. rotunda*, *P. costellata* and *P. cubensis*. The ornamentation is suggestive of *Argyrotheca* rather than *Phragmorthis*.

Phragmothyris rotunda
Cooper, n. sp.
Plate 15, E, figures 24–32

Shell large for the genus, rounded in outline but slighly wider than long; hinge narrower than the shell width; sides and anterior margin well rounded; anterior commissure straight; surface marked by broadly rounded costae numbering 30 to 40 at the front margin; increase of costae is by intercalation.

Pedicle valve unevenly convex in lateral profile, the posterior half having the greater convexity, the anterior half somewhat flattened, anterior profile strongly convex. Umbonal and beak regions worn away; posteromedian region inflated; anterior

somewhat flatttened; flanks gently convex and steep-sided. Interarea strongly apsacline; symphytium remnants small.

Brachial valve moderately convex in lateral profile and broadly and moderately convex in anterior profile; umbo and median region moderately swollen; anterior and lateral slopes about equally inclined, moderately steep. Muscle callosities moderately elevated.

Measurements in millimeters:

	Length	*Brachial length*	*Mid-width*	*Hinge width*	*Thickness*
Holotype	11.8	10.7	13.5	10.2	8.0
561509a	13.4	12.9	15.5	11.0	10.8

Types.—Holotype: USNM 561508a; figured paratype: USNM 561508b; measured paratype: USNM 561509a; unfigured paratypes: USNM 561509b–f.

Horizon and locality.—Eocene in Cuba, north of Carretera Central, 2.1–2.2 miles on road to San Diego los Banos, Habana Province.

Discussion.—This is the largest of all the known species of *Phragmorthyris*. The species is most like *P. costellata* and the differences and similarities are discussed under that species. The median ridge reaches its most elaborate development in this species.

PHRAGMOTHYRIS SUBPLANA
Cooper, n. sp.
Plate 15, A, figures 1–6;
G, figures 39–46

Shell of about medium size for the genus, subrectangular in outline, wider than long but with the hinge narrower than the midwidth. Sides gently rounded; anterior margin broadly rounded; cardinal extremities narrowly rounded. Anterior commissure broadly sulcate. Surface marked by about 32 broadly rounded costellae, increasing by intercallation in three generations; costellae beaded near the margins.

Pedicle valve gently convex in lateral profile and with the maximum convexity in the posterior half; anterior profile broadly and moderately domed. Umbonal and median regions somewhat narrowly swollen to form a poorly defined median fold. Flanks flattened and with long, steep slopes to the margins. Interarea short, strongly apsacline. Foramen large.

Brachial valve gently convex in lateral profile and with the maximum convexity in the posterior half, anterior half somewhat flattened. Anterior profile broadly and faintly convex. Umbonal region gently convex; sulcus originating just anterior to umbo, broad and shallow; flanks bounding sulcus gently convex.

Measurements in millimeters:

	Length	*Brachial length*	*Mid-width*	*Hinge width*	*Thickness*
Holotype	9.9	9.1	10.7	8.4	5.5
Paratype 561498	10.6	10.2	13.3	11.4	6.2

Types.—Holotype: USNM 561500a; figured paratypes: USNM 561498, 561500b.

Horizon and locality.—Eocene in Cuba (1640) in deep cut north of Grua 9, Ramal Juan Criollo, Camaguey Province; (1102) 4.65 kilometers west of Guanajay on the road to Mariel, Pinar del Rio Province; Oligocene in Cuba (1660) in the long cut south of the Y-switch Ramal Valle, Central Jatibonico, Camaguey Province.

Discussion.—This species is more suggestive of *Argyrotheca* than the more convex types. Its costellae are more like some forms of *Argyrotheca* than the costellae of *P. costellata*, *P. rotunda* or *P. cubensis*. The brachial valve is distinctly convex but only moderately so. The anterior half or less of the brachial valve is flattened to concave and a shallow sulcus is perceptible. The species thus differs from *P. rotunda*, *P. costellata* and *P. cubensis* in its shallow brachial valve and strong costellation. It differs from *P. palmeri* in not possessing a symphytium. The median septum is short and erect but not curved posteriorly.

MANUSCRIPT RECEIVED June 12, 1954

(*For explanation of Plate 15, please turn to next page*)

EXPLANATION OF PLATE 15

A. *Phragmothyris subplana* Cooper, n. sp. (p. 69)

FIGS. *1–6—1–5*, Respectively anterior, side, brachial, pedicle and posterior views of a complete specimen, ×1, paratype USNM 561498; *6*, brachial view of the same specimen ×2.
Oligocene in long cut south of Y-switch Ramal Valle, Central Jatibonico, Camaguey Province, Cuba.

B. *Phragmothyris costellata* Cooper, n. sp. (p. 67)

FIGS. *7–15—7–10*, Respectively posterior, brachial, side and anterior views of the holotype, USNM 561502a; *11, 12*, respectively posterior and brachial views of the holotype, ×2; *13, 14*, interior and posterior views of the brachial valve, ×3, showing septum with spoon-like plate, paratype USNM 561502b; *15*, interior of another brachial valve, ×3, showing muscle platform and median septum, paratype USNM 561502c.
Eocene, 4.65 km. west of Guanajay on road to Mariel, Pinar del Rio Province, Cuba.

C. *Orthothyris radiata* Cooper, n. sp. (p. 65)

FIGS. *16–20*, Respectively anterior, pedicle, side, brachial and posterior views of the holotype, USNM 108687.
Upper Cretaceous, 1 km. west of Central San Antonio, Habana Province, Cuba.

D. *Phragmothyris costellata* Cooper, n. sp. (p. 67)

FIGS. *21–23*, Respectively normal interior view, a view of the shell tilted and a view of the same shell tilted to the side, brachial valve, ×3, paratype USNM 561507. Shows septum with spoon-like plate, and base of loop on each side of it.
Eocene (Cojimar), 1.5–2.5 km. west of Cojimar on the road to Casa Blanca, Habana Province, Cuba.

E. *Phragmothyris rotunda* Cooper, n. sp. (p. 68)

FIGS. *24–32—24–28*, Respectively pedicle, posterior, side, anterior and brachial views of the holotype, ×1, USNM 561508a; *32*, brachial view of the holotype, ×2; *29–31*, normal, side and posterior views of the brachial interior, ×2, showing median septum, muscle platforms and base of loop, paratype USNM 561508b.
Eocene, north of Carretera Central, 2.1–2.2 miles on road to San Diego los Banos, Habana Province, Cuba.

F. *Phragmothyris palmeri* Cooper, n. sp. (p. 68)

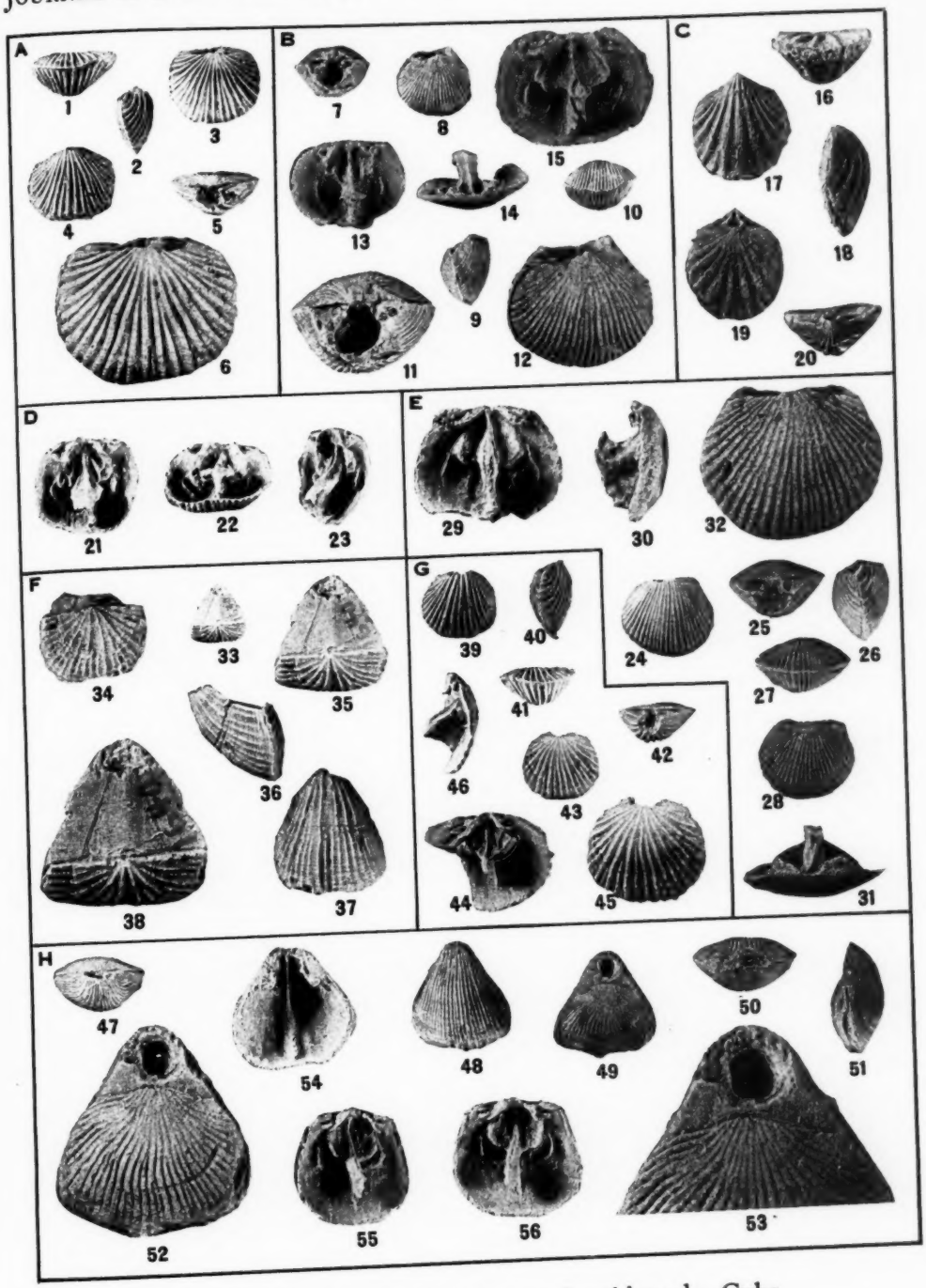
FIGS. *33–38—33*, Posterior view of the holotype, ×1, USNM 561506; *34–37*, respectively brachial, posterior, side and pedicle views of the holotype, ×2; *38*, posterior view of the holotype, ×3, showing large delthyrial plate.
Eocene, deep cut north of Grua 9, Ramal Juan Criollo, Camaguey Province, Cuba.

G. *Phragmothyris subplana* Cooper, n. sp. (p. 69)

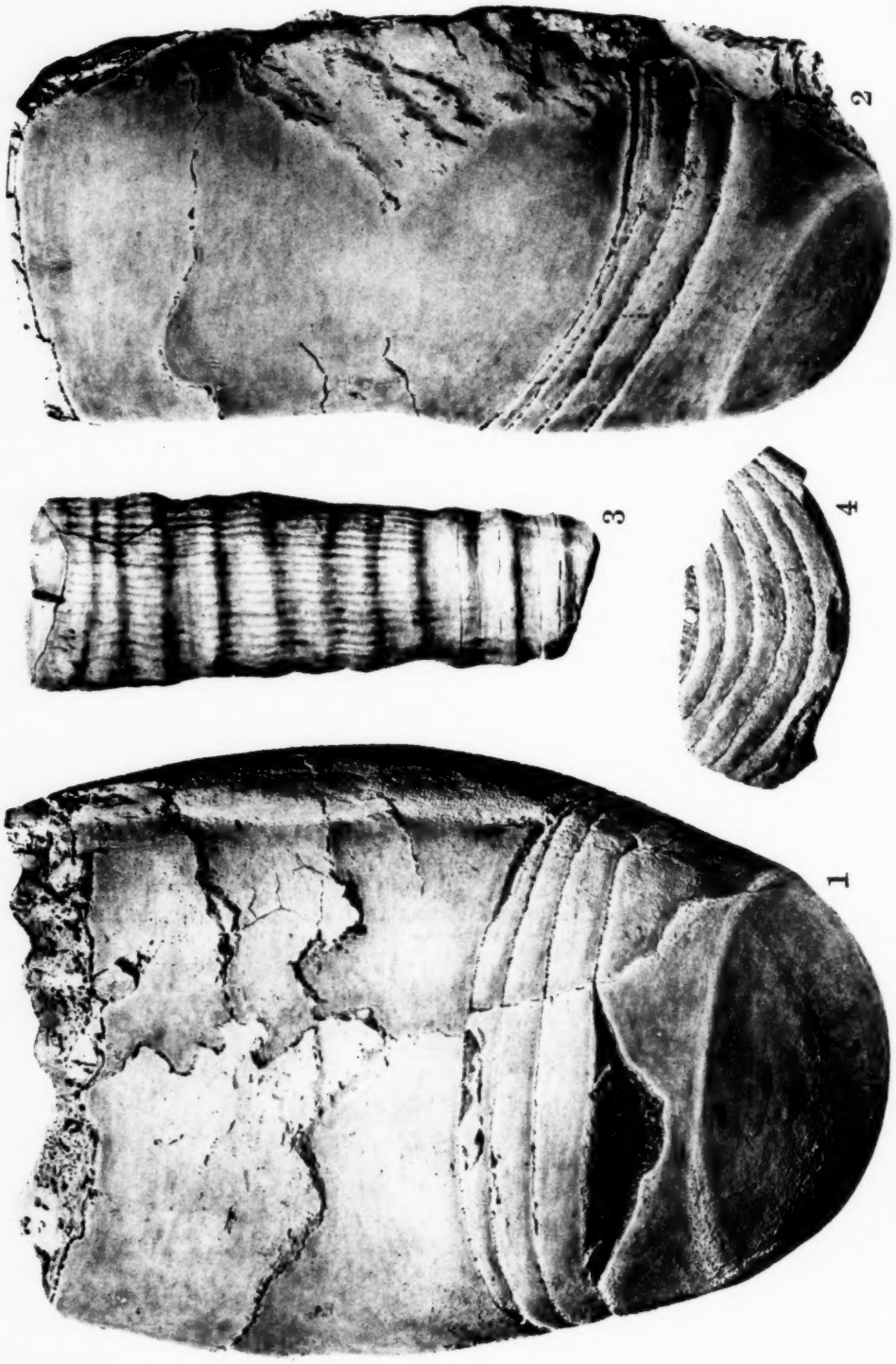
FIGS. *39–46—39–43*, Respectively pedicle, side, anterior, posterior and brachial views of the holotype, ×1, USNM 561500a; *45*, brachial view of the holotype, ×2; *44, 46*, side and normal view of the brachial interior showing septum, muscle platform and base of loop, ×2, paratype USNM 561500b.
Eocene, deep cut north of Grua 9, Ramal Juan Criollo, Camaguey Province, Cuba.

H. *Phragmothyris cubensis* Cooper, n. sp. (p. 67)

FIGS. *47–56—47–51*, Respectively posterior, pedicle, brachial, anterior and side views of the holotype, ×1, USNM 561504a; *52*, brachial view of holotype, ×2; *53*, view of apical region of holotype, ×3, showing remnant of delthyrial plate; *54*, interior of the pedicle valve showing medium septum, ×2, paratype USNM 561504b; *55, 56*, brachial interior tilted to the side and in normal view, ×3, showing muscle platform, median septum and base of loop on each side of muscle platform, paratype USNM 561504c.
Eocene, deep cut north of Grua 9, Ramal Juan Criollo, Camaguey Province, Cuba.



Cooper, Cretaceous and Eocene brachiopods, Cuba



Sweet, Ordovician cephalopods, Colorado

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CEPHALOPODS FROM THE FREMONT FORMATION OF CENTRAL COLORADO

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ABSTRACT—Altogether, 17 genera of nautiloids are now known to occur in the lower portion of the Fremont formation of central Colorado. Representatives of nine of these, including *Actinoceras*, *Beloitoceras*, *Cyclendoceras*, *Ephippiorthoceras*, *Endoceras*, *Kionoceras*, *Lambeoceras*, *Probillingsites*, and *Spyroceras* are described in this report. The Fremont nautiloids are part of the widespread "arctic Ordovician" fauna best known from the Red River formation of southern Manitoba and the Bighorn formation of Wyoming. This fauna is interpreted to be early Upper Ordovician in age. One specimen of *Allumettoceras* is described from the upper (Priest Canyon) member of the Fremont, which, because of the associated brachiopods, is considered to be Richmond in age. One new species is described: *Probillingsites kessleri*.

INTRODUCTION

IN HIS report on the fish remains of the Middle Ordovician Harding sandstone, near Canon City, Colorado, Walcott (1892) called attention to the occurrence of cephalopods near the base of the overlying Fremont formation. From the lower part of this formation, he listed *Endoceras*, *Ormoceras*, *Orthoceras*, *Gomphoceras*, *Cy[r]toceras*, and *Lituites;* and from the upper, thin-bedded portion of the formation, he listed *Orthoceras*, *Endoceras*, and *Gomphoceras*. This material, and additional specimens collected by S. W. Loper, were studied by Foerste in 1935, who recognized in the assemblage representatives of *Charactoceras*, *Cyrtogomphoceras*, *Fayettoceras?*, *Fremontoceras*, *Neumatoceras*, *Richardsonoceras*, *Diestoceras*, and *Nanno*.

During the summers of 1952 and 1953, the writer and Bruce O. Nolf, then of the State University of Iowa, spent several months in the field making a stratigraphic study of the Harding and Fremont formations, and we secured several additional nautiloids not heretofore known from the Fremont. In addition, three specimens were loaned to the writer by Mr. F. C. Kessler, Curator of the Canon City Municipal Museum, in Canon City, and the collection of Fremont invertebrates at the Colorado School of Mines was made available for study by Professor J. Harlan Johnson. The assemblage was further augmented by a number of specimens collected by Dr. John C. Frye while he was connected with the University of Kansas. The writer expresses his appreciation to these men for making the present collection possible. He is further indebted to Professors A. K. Miller and W. M. Furnish of the State University of Iowa for their advice and encouragement during the preparation of the report. The project was financed in large part by the National Science Foundation and the Graduate College of the State University of Iowa.

The Fremont formation was named and first described by Walcott (1892) from typical exposures of the unit on the lower slopes of Fremont Peak, about a mile northwest

EXPLANATION OF PLATE 16

FIGS. *1*, *2*—*Probillingsites kessleri* Sweet, n. sp. Dorsal and lateral views of the holotype, ×½, from massive dolomite member of Fremont formation, about 2 miles northwest of Canon City, Colorado. (p. 80)

3—*Spyroceras* sp. Lateral view of an internal mold, ×1; from massive dolomite member of Fremont formation, near Canon City, Colorado. (p. 81)

4—*Lambeoceras* sp. Lateral view of an incomplete internal mold, ×1; from massive dolomite member of Fremont formation, in unnamed valley tributary to Wilson Creek, Fremont County, Colorado. (p. 79)

of the state penitentiary at Canon City, Colorado. Recent studies (Sweet, 1954) indicate that the formation crops out throughout much of central Colorado west of Canon City, and is one of the most prominent horizon markers in the Paleozoic section of that part of the state. The writer recognizes two members within the Fremont, each of which is remarkably uniform in lithologic character throughout the area of outcrop.

Massive dolomite member.—Immediately overlying the clastics of the Harding formation, in most parts of central Colorado, is a massive, buff or gray dolomite which weathers with a rough, pitted surface, and contains a prominent zone of corals, *Receptaculites*, and nautiloids near its base. The mid-portion of the member is cherty, and the presence of banded chert or "agate" in it near Oak Creek, south of Canon City, has resulted in the name "Specimen Hill" for the locality. The massive dolomite member is the most widespread portion of the formation, and has a maximum thickness of 208 feet, in the Canon City region. All but one of the cephalopods described in this report were collected from a zone 1 to 25 feet above the base of the massive member in the Canon City region, here they were associated with *Receptaculites*, *Halysites*, *Streptelasma*, *Calapoecia*, *Rhynchotrema* [*Lepidocyclus?*], and others.

Priest Canyon member.—This name has been applied (Sweet, 1954) to the sequence of thin-bedded, argillaceous, fine-grained dolomite which overlies the massive member throughout the central portion of the outcrop area. The type section is in Priest Canyon, about 4 miles northwest of Canon City, Colorado. In the Canon City region, a persistent 4- to 8-foot bed of cherty, dolomitic shale occurs at the base of the member, but this unit is not present in sections west of Canon City. The lower 5 feet of the dolomite is conspicuously fossiliferous in nearly all of the sections studied, but the succeeding strata are only sparingly so. The member reaches a maximum thickness of 211 feet, in the Kerber Creek area near the head of the San Luis Valley in south-central Colorado. At the type locality, it is only 75 feet thick, and becomes thinner to both the north and south. One cephalopod was collected by the writer from the Priest Canyon member at the type locality, and it is described in this report.

The Fremont formation is separated from the Harding formation, and from superjacent formations by rather well-defined physical and faunal unconformities. Throughout most of its outcrop area, the Fremont is overlain by deposits of known Upper Devonian age, but along the east flanks of the Front Range and the Wet Mountains, the overlying strata range from Devonian? to Jurassic in age. The contact between the Fremont and the subjacent Harding formation is everywhere abrupt, and non-gradational; in a number of sections there is evidence that the Harding was rather deeply channeled prior to the deposition of the Fremont, and a distinct erosional unconformity exists between the two formations along Oil Creek, north of Canon City. Furthermore, the Harding conodont fauna indicates that it should be correlated with the Glenwood beds of Minnesota and Iowa, whose lower Black River age has been well established.

The writer's collection from the massive dolomite member of the Fremont contains representatives of the following cephalopod genera: *Actinoceras*, *Beloitoceras*, *Cyclendoceras*, *Ephippiorthoceras*, *Endoceras*, *Kionoceras*, *Lambeoceras*, *Probillingsites*, and *Spyroceras*. The genus *Actinoceras*, as now generally delimited, is world-wide in its distribution, and is widespread and abundant in the Middle and Upper Ordovician of North America. It is represented in the present collection by several specimens, none of which is specifically identifiable.

Beloitoceras, of which many species are known, is abundantly represented in the Middle and Upper Ordovician of North America. It is, however, rare in other parts of the world. Typical representatives of it are probably most numerous in strata regarded as Middle Ordovician in age, but faintly gibbous forms, such as the Fremont specimen described in this report, appear to be more common in the Upper Ordovician.

Annulated endoceratoids, referable to *Cyclendoceras*, are among the most abundant of the Fremont nautiloids, just as in the Lander sandstone of western Wyoming, the Whitewood dolomite of South Dakota,

and the Red River formation of southern Manitoba. Although the genus is widespread geographically, occurring in North America, Europe, and Asia, it appears to be confined stratigraphically to the Middle and Upper Ordovician. Two Fremont specimens are referred to *C. cylindricum* Miller, which was originally described from the Lander sandstone of Wyoming.

Representatives of the genus *Ephippiorthoceras* have been reported from many localities in North America, where they are almost entirely restricted to rocks of Upper Ordovician age. One species, *E. sigmoidale* Parks, is known from rocks of upper Trenton age in Ontario, and two from the Silurian, *E. ekwanense* Foerste and Savage from Ontario, and *E. decorum* Teichert and Glenister of Tasmania. The genus is also known from the Ordovician of Greenland and Norway.

Endoceras, like *Cyclendoceras*, is abundant in the lower member of the Fremont. Indeed, representatives of these two genera form the bulk of the writer's Fremont collection. *Endoceras* is world-wide in its distribution and ranges from at least as low as the Middle Ordovician well up into the Silurian. In North America, however, it appears to be most abundant in the Middle and Upper Ordovician.

Kionoceras, as it is now broadly interpreted, is known from many parts of the world, and, although it is apparently most abundant in the Middle Silurian, is known to range stratigraphically from the Lower Ordovician through the Upper Pennsylvanian. Consequently, little stratigraphic value can be assigned to the single specifically indeterminate specimen from the Fremont.

With the possible exception of an atypical specimen described by Flower from the upper Trenton Terrebonne formation near Montreal, *Lambeoceras* is characteristic of the "arctic Ordovician" fauna typically developed in the Red River and Bighorn formations. The genus is widespread in the Upper Ordovician of North America, and except for Flower's specimen of uncertain generic affinities, representatives of this distinctive form have not been found below the Stewartville formation of the Upper Mississippi Valley. *Lambeoceras* occurs in the Whitewater formation of the Richmond group in Indiana, the Lander sandstone of western Wyoming, the Red River formation of southern Manitoba, the Whitewood dolomite of South Dakota, and in equivalent strata on Baffin Island and Greenland. While the writer has only one incomplete specimen from the lower member of the Fremont formation, it may well be one of the most significant fossils in his collection.

Probillingsites is rather uncommon, and the Fremont form described in this report is without counterpart among described species of the genus because of its unusually large size. All of the known species of *Probillingsites* come from the Middle and Upper Ordovician of North America, but the genus is probably best known from Middle Ordovician forms. It should be pointed out, however, that Upper Ordovician species of *Probillingsites* differ in certain respects from typical Middle Ordovician forms, and it is with the former group that the Fremont form seems to have its closest affinities.

In recent years, *Spyroceras* has been so much revised that the writer is not sure just what should be placed in it. As it is here interpreted, that is, in its original broad sense, the genus ranges stratigraphically from at least the Upper Ordovician into the Middle Devonian. Representatives of *Spyroceras* are known from the Lander sandstone of western Wyoming, the Whitewood dolomite of South Dakota, and from most of the horizons in Canada and the Canadian Arctic which have yielded the typical "arctic Ordovician" cephalopod fauna.

Only one nautiloid, a specifically indeterminate internal mold of *Allumettoceras*, was collected by the writer from the Priest Canyon member of the Fremont formation. It is probably the highest recorded occurrence of this genus.

Charactoceras, *Cyrtogomphoceras*, and *Diestoceras*, described by Foerste from the Fremont, are all rather common fossils in rocks of Upper Ordovician age. The genotype of *Charactoceras* is from the Whitewater formation of the typical Richmond; and congeneric forms are known from the Richmond of Illinois, Missouri, and Iowa, the Stewartville formation of Minnesota, the English Head and Vauréal formations of Anticosti Island, the Cape Calhoun beds of

Greenland, the Lyckholm formation of Estonia, the *Trinucleus* limestone of Norway, and the Trenton of New York.

Cyrtogomphoceras, as noted by Foerste (1929, p. 139), is one of the most characteristic and widely distributed genera of cephalopods in the Red River formation, and it is known from related strata as far north and east as Greenland. The genus has also been reported from the Bighorn formation of Wyoming, and the equivalent Whitewood dolomite of South Dakota. *Diestoceras*, which is related to *Cyrtogomphoceras*, is also abundant in Upper Ordovician strata, but it is known to range from Chazyan to Lower Silurian.

In addition, it should be pointed out that *Neumatoceras* is now generally regarded as a synonym of *Westonoceras*, and the genus is widespread and abundant in the Upper Ordovician of North America. It also occurs in the Middle Ordovician of Minnesota, Michigan, Kentucky, and Missouri, and probably in the Upper Ordovician of Scotland and Norway.

Fremontoceras was first described from the Fremont, and since its establishment in 1935, the genus has been reported from only two other localities (Flower, 1952), both in the "uppermost Trenton" of eastern North America. Furthermore, considerable doubt has been cast (Flower, 1946, pp. 162–163) upon the status of *Nanno*, hence it is unwise at present to accord it much significance in the interpretation of the Fremont fauna.

Richardsonoceras is known from specimens which have been collected from the Platteville of Wisconsin, the Black River of Ontario, the Wright Bay formation on the southern coast of Washington Land in northwestern Greenland, the Lander sandstone of western Wyoming, and the Bighorn formation of the Bighorn Mountains of Wyoming. It thus appears that the genus is best known in the Middle Ordovician. Flower (1946, p. 319) points out that *Richardsonoceras* is gradational with both *Beloitoceras* and *Oonoceras*, and suggests that it might possibly be regarded as a synonym of the latter, which ranges into the Middle Silurian.

As far as the writer can ascertain, *Fayettoceras* is known from only three species, one of which, *F.? canyonense* Foerste, was established to include forms from the Fremont formation. The type species, *F. thompsoni*, comes from the upper portion of the Saluda formation of southern Indiana, and the only other species known is from the Platteville formation of Wisconsin. However, this last specimen is only questionably referable to *Fayettoceras*, so it appears that definite representatives of the genus are known only from the Upper Ordovician of North America.

From the data presented in the preceding discussion, it is clear that the cephalopods from the lower member of the Fremont formation find their closest relationships in the so-called "arctic Ordovician fauna" which is known best from the Red River formation of southern Manitoba, and the Bighorn formation of Wyoming. The fauna is also well-developed in the Whitewood dolomite of South Dakota, the Stewartville formation of the Upper Mississippi Valley, the Nelson River and Shamattawa formations of the region southwest of Hudson Bay, the Liskeard formation of the Lake Timiskaming region, and the shale at Silliman's Fossil Mount in the southern part of Baffin Island. Southern extensions of this fauna are reported from the Viola formation of Oklahoma, the Montoya formation of western Texas and New Mexico, and probably from the Burnam limestone of the Llano uplift in central Texas. The Fish Haven dolomite of Utah and southern Idaho is also closely equivalent. Of the 17 genera of nautiloids now known from the basal member of the Fremont, 10 also occur in the Bighorn formation, and a like number are known to be present in the Red River formation. Furthermore, *Endoceras* and *Cyclendoceras* are abundant in all three faunas.

While there can be little doubt that all of the strata from which the "arctic fauna" has been described are of nearly the same age, an exact classification is as yet a debated point. Foerste (1924, 1935) chose to regard the age as Richmond, and he has been followed in this viewpoint by many others (Twenhofel et al., 1954). The boreal fauna makes its first appearance in the Waynesville formation of the type Richmond (Flower, 1946, pp. 125–126) and reaches the

climax of its development in that region in the Whitewater and Saluda formations of the same group. Taken alone this would certainly seem to indicate that a Richmond age for the "arctic fauna" was wholly tenable. However, in a continuation of his excellent studies of the Ordovician cephalopods of eastern North America, Flower (1952, pp. 25–26) has demonstrated that many of the arctic nautiloid genera appear for the first time in that region in rocks that are ". . . of unquestionably late Trenton age." He further points out that a number of the characteristic boreal nautiloids have not, as yet, been found in strata of undisputed Richmond age. This is certainly true of the Fremont genera *Cyrtogomphoceras*, *Ephippiorthoceras*, and *Fremontoceras*. However, it is also true that such forms as *Lambeoceras*, gibbous *Beloitoceras*, *Characoceras*, and *Fayettoceras* are best known from, or have their affines in strata of Richmond age. *Probillingsites* from the Fremont also appears to be more closely related to Upper Ordovician forms than to those described from the Middle Ordovician.

In 1925, and again in 1930, Kirk suggested that the age of these rocks be regarded as Cincinnatian—in the sense of being post-Trenton, but pre-Richmond—a view that Flower (1952, p. 26) is now apparently inclined to accept, and one which the writer finds to be most satisfactory. Furthermore, brachiopods from the Priest Canyon member of the Fremont formation appear to be closely related to those described (Wang, 1949) from the Richmond Maquoketa shale of Iowa, and the Priest Canyon is apparently gradational with the underlying massive member. Hence, it is concluded that the lower member of the Fremont formation is early Upper Ordovician in age, and that the Priest Canyon member is probably Richmond. Further study of the Priest Canyon brachiopods will almost certainly result in a more precise classification of the latter member.

SYSTEMATIC DESCRIPTIONS

ACTINOCERAS sp.
Plate 17, figures 1, 2

Actinoceratoids are not uncommon in the lower member of the Fremont, and the writer's collection contains several specimens which undoubtedly belong to this group. Only one of these, however, is well enough preserved that generic assignment can be made with certainty. This specimen is an incomplete internal mold 43 mm. long, which is broken in such a fashion that three segments of the siphuncle are exposed on its ventral side. A portion of the dorsum, and one of the lateral zones are not preserved. The specimen represents four and one-half camerae of a phragmocone which is approximaely circular in section, and expands fairly rapidly from a diameter of about 18 mm. at the adapical end to an approximated diameter of 25 mm. at the adoral end. The sutures appear to cross the dorsum transversely, but are directed strongly apicad in the lateral zones so as to cross the venter as relatively deep lobes. The siphuncle is large, subcircular in cross-section, and is composed of relatively short, tubular septal necks, and broadly expanded, nummuloidal connecting rings which are adnate to the upper surfaces of the immediately subjacent septa. The siphuncle is ventral, and the outer sides of the connecting rings are flattened where they were in contact with the venter. The rings are about 6 mm. in length, and are adnate to the septa for the lower 2 mm. of this distance. The septal necks are about 1.5 mm. in length. At the adapical end of the specimen, the siphuncle is approximately 8 mm. in diameter where it passes through the adapical septum, expanding to a diameter of 12 mm. in the superjacent connecting ring.

Occurrence.—Three inches above the base of the Fremont formation, in an unnamed valley tributary to Wilson Creek, about sec. 25, T. 17 S., R. 71 W., Fremont County, Colorado.

Repository.—State University of Iowa, 8053.

BELOITOCERAS ACCULTUM Foerste
Plate 17, figures 4, 5; text-figure 1B

Beloitoceras accultum FOERSTE, 1928, Canada Geol. Survey Mem. 154, pp. 308–309, pl. 50, fig. 1; pl. 51, fig. 1.

The single Fremont specimen which is being referred to this species is a nearly complete, slightly compressed internal mold 62

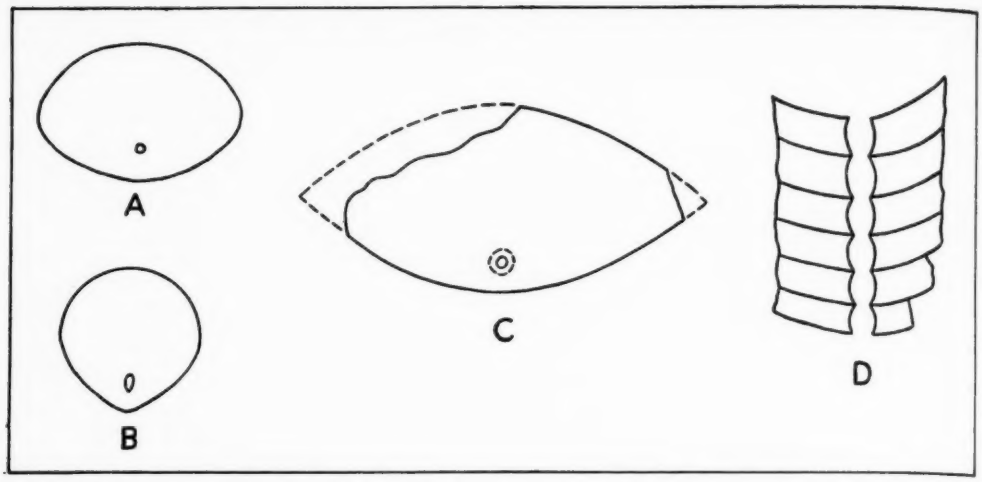

FIG. 1—A. Diagrammatic cross-section of *Allumettoceras* sp., ×2. B. Diagrammatic transverse section of *Beloitoceras accultum* Foerste, ×1. C. Diagrammatic transverse section of *Lambeoceras* sp., ×1. D. Diagrammatic longitudinal section of the adapical six camerae of *Ephippiorthoceras formosum* (Billings), ×1.

mm. in length, of which 27 mm. is body chamber and the remaining 35 mm. represents 15 camerae of the phragmocone. The venter is uniformly convex, with a radius of curvature of about 70 mm. In general, the dorsum is faintly concave, but there is a slight convexity a few mm. above the base of the body chamber. The conch expands from dorso-ventral and lateral diameters of 13 mm. and 12 mm. at the adapical end to corresponding diameters of 29 mm. and 28.5 mm. at the adapical end of the body chamber. The conch has a maximum width of 30.5 mm., 12 mm. above the adapical end of the body chamber. Dorso-ventral and lateral diameters at the adoral end of the specimen are 28 mm. and 27 mm. respectively, and it is probable that these measurements would be somewhat less at the aperture if it were preserved. In textfigure 1B, which portrays a section transverse to the long axis of the conch, the outline is faintly lachrymiform, the venter being somewhat more sharply rounded than the dorsum. In the adapical portion of the phragmocone, the sutures are directly transverse to the long axis of the conch, but orad they slope gently orad from the dorsum. The adoral 9 sutures show relatively sharp, low, ventral saddles which increase in sharpness orad. On the venter, 11 camerae occur in a length equal to the maximum dorso-ventral diameter of the conch. The convexity of the septa equals the length of one camera. The siphuncle is small, and is 1.5 mm. from the venter where it passes through the sixth septum above the apical end. It is subcircular in transverse section, but has an elliptical outline on the inclined septal face. Nothing is known of its structure.

Discussion.—This specimen agrees closely with the figured type from the English Head formation of Anticosti Island. The type is somewhat more compressed laterally, and shows greater gibbosity on the body chamber than does the Fremont specimen, but in size, rate of expansion, dimension of camerae, and configuration of sutures, the two are closely similar. *B. accultum* differs from *B. magisterium* Foerste in the lack of a distinctly oval transverse section, and in the fact that the dorsal gibbous region is distinctly nearer the aperture. The Fremont specimen stands close to *B. amoenum* (Miller) and *B. cumingsi* Flower from the Cincinnatian of Ohio, but differs from those species in the greater rate of expansion of the phragmocone, and the more adoral position of the dorsal gibbosity. Flower (1946, p. 276) points out that our present knowledge indicates that these large, faintly gibbous species of *Beloitoceras* are confined to the

Upper Ordovician, and might serve as useful stratigraphic indices.

Occurrence.—Basal portion of Fremont formation, in the Colorado Fuel and Iron Company Quarry, about 2 miles northwest of Canon City, Colorado.

Repository.—Canon City Municipal Museum, Amick Wing, 78.

CYCLENDOCERAS CYLINDRICUM Miller
Plate 17, figure 8; plate 18, figure 6

Cyclendoceras cylindricum MILLER, 1932, Trans. Conn. Acad. Arts and Sci., vol. 31, pp. 235–236, pl. 9, fig. 1.

Two specimens from the lower member of the Fremont formation are being referred to this species. The first of these (Pl. 17, fig. 8) is an imperfectly preserved internal mold representing seven and one-half camerae of an incomplete phragmocone 178 mm. in length and nearly circular in cross-section. The dorso-ventral diameter of the conch at the adoral end of the specimen is 80 mm., and the corresponding lateral diameter is only slightly less. In a length equal to the dorso-ventral diameter there are five and one-half camerae. The sutures are nearly transverse to the long axis of the conch, but a slight sinuosity produces broadly rounded lateral saddles and corresponding dorsal and ventral lobes. The surface of the mold is crossed by many prominent, rounded, ridge-like annulations, which rise 1.5–2 mm. above the concave depressions which separate them. Twelve annulations occur in a distance equal to the dorso-ventral diameter. On the dorsum, these annulations are nearly transverse to the long axis of the conch, but on the lateral zones, they curve strongly apicad, crossing one and one-half to two camerae. They cross the venter as broad, shallow lobes. The siphuncle is ventral, and circular in cross-section. Near the adoral end of the specimen, it measures 37 mm. in diameter, and appears to have been in contact with the ventral wall at that point.

The second specimen referred to this species (Pl. 18, fig. 6) is an incomplete internal mold of a faintly annulated phragmocone 340 mm. in length, which represents portions of 26 camerae. The conch expands from estimated dorso-ventral and lateral diameters of 85 mm. and 104 mm. in the seventh camera orad of the adapical end, to corresponding diameters of 95 mm. and 110 mm. at the adoral end, indicating a very small apical angle. The sutures are slightly sinuous, forming low lateral saddles and somewhat sharper dorsal and ventral lobes. It is probable, however, that the degree of curvature of the ventral lobes is due in part to distortion which has flattened the ventral side of the conch. Seven camerae occur in a distance equivalent to the maximum dorso-ventral diameter. The annulations are faint, and are preserved only near the adapical end of the specimen where they form low, narrowly rounded ridges separated by slightly concave interspaces several times their width. In a distance equal to the maximum diameter, there are 12–14 annulations indicating that these are somewhat more closely spaced than the sutures. No annulations are preserved on the dorsal side, but in the one lateral zone which is preserved, they curve strongly apicad, crossing one and one-half to two camerae. Apparently, they form broad ventral lobes. The siphuncle is large, ventral, and is dorso-ventrally depressed. At the adoral end of the conch, it has a dorso-ventral diameter of about 40 mm. and a lateral diameter of about 45 mm., indicating that it was probably circular in section prior to distortion.

Discussion.—The two Fremont specimens probably differ more from one another than either of them differs from the types of *C. cylindricum* Miller, but most of this variation appears to be attributable to differences in preservation. In cameral ratio, the insignificant amount of expansion, cross-sectional shape, and size of siphuncle, the Fremont specimens agree with the types from the Lander sandstone of western Wyoming. However, the annulations on the specimens at hand are somewhat more numerous than is apparently the case in the types, and this may be a property of sufficient importance to justify specific distinction. *C. cylindricum* differs from *C. boreale* Foerste in the smaller size of its siphuncle, and its relatively shorter camerae.

Occurrence.—Massive dolomite member of Fremont formation, in the Colorado Fuel and Iron Company Quarry, about 2 miles northwest of Canon City, Colorado; from base of same member in Priest Canyon, nearly 4 miles northwest of Canon City.

Repository.—Canon City Municipal Museum, Amick Wing, 79; State University of Iowa, 8054.

ENDOCERAS sp.
Plate 18, figure 5

There are a number of representatives of *Endoceras* in the writer's Fremont collection; however, none of them are well enough preserved to identify specifically. The most nearly complete specimen is illustrated by figure 5 on plate 18. This specimen is a somewhat distorted internal mold 188 mm. in length, which represents 15 camerae of the phragmocone. It has estimated dorso-ventral and lateral diameters of 73 mm. and 91 mm. respectively near its adapical end; comparable measurements near the adoral end are 92 mm. and 105 mm., which indicates a very small apical angle. The camerae average slightly more than 12 mm. in length, so that there are eight and one-half camerae in a distance equal to the maximum lateral diameter. The sutures are simple, straight, and directly transverse to the long axis of the conch; and they have a curvature amounting to about two-elevenths the maximum lateral diameter. The siphuncle is large, subcircular in cross-section, and is located 13 mm. (estimated) from the venter at the adoral end. In this section, it is about 41 mm. in diameter, or approximately two-fifths the maximum width of conch. In transverse section, the specimen is elliptical in outline, and it appears from reconstruction that the dorsum is more sharply convex than the venter, although at least part of this shape is due to distortion.

The balance of the specimens in the collection at hand indicates considerable variation in size, but in most of them, the cameral ratio and the relative size and position of the siphuncle appear to be similar to those of the specimen just described.

Occurrence.—Basal portion of massive dolomite member, Fremont formation, in unnamed valley tributary to Wilson Creek, about sec. 25, T. 17 S., R. 71 W., Fremont County, Colorado (2 specimens); from same part of formation in Priest Canyon, about 4 miles northwest of Canon City (8 specimens).

Repository.—State University of Iowa, 8055–8064.

EPHIPPIORTHOCERAS FORMOSUM (Billings)
Plate 17, figure 3; text-figure 1D

Orthoceras formosum BILLINGS, 1857, Canada Geol. Survey, Rept. Progress 1853–1856, p. 317;——BILLINGS, 1866, Cat. Silurian Fossils Anticosti, pp. 22, 58.

Ephippiorthoceras formosum FOERSTE, 1928, Canada Geol. Survey Mem. 154, pp. 270–271; ——FOERSTE, 1928, Trans. Roy. Soc. Canada, 3rd ser., pt. 2, sec. 4, p. 226, pl. 3, figs. 1A, B, C, 2, 4A, B.

One specimen from the massive dolomite member of the Fremont formation appears to be referable to this species. It is a rather well-preserved internal mold 57 mm. long, representing eight complete camerae of the phragmocone and 18 mm. of the body chamber. The conch is subcircular in cross-section, being slightly flattened laterally. It expands from a dorso-ventral diameter of 22 mm. at its adapical end to a corresponding diameter of 29 mm. at the adoral end of the specimen, indicating an apical angle of somewhat more than 8 degrees. At the adapical end of the body chamber, the specimen has dorso-ventral and lateral diameters of 27.5 mm. and 24.5 mm. respectively.

The camerae average 4.7 mm. in length, but increase from slightly more than 4 mm. at the adapical end to about 5 mm. at the adoral end of the phragmocone. In a distance equivalent to the maximum diameter of the conch there are four and one-half camerae. The sutures form broad lateral lobes whose "troughs" lie about 5 mm. apicad of the "crests" of the adjacent dorsal and ventral saddles. These saddles are more sharply curved than the lateral lobes, the one on the dorsum rising slightly more than 1 mm. farther orad than the corresponding one on the venter.

The conch is very slightly curved lengthwise, the dorsal side being slightly concave and the ventral side slightly convex. No trace of surface ornamentation is preserved. The siphuncle is small, subcentral, and its center lies 11 mm. from the venter at the adapical end of the specimen. Details of a longitudinal section through the adapical six camerae are elucidated by text-figure 1D, and from this diagram it can be seen that the siphuncle maintains its nearly central position, and expands slightly within the camerae to form subfusiform segments.

Discussion.—This species was evidently based upon three more or less imperfectly preserved specimens from the Upper Ordovician on Anticosti Island. Only two of these specimens have been preserved, the largest of which Foerste has designated as the holotype because it preserves portions of the ornamented shell. The smaller of the two original specimens differs from the designated type in that its camerae are somewhat longer, and no trace of surface ornamentation is preserved. The Fremont specimen also agrees closely with the figured paratype, which is similar to a specimen collected by Twenhofel on Anticosti Island (Foerste, 1928, pl. 3, fig. 2).

Occurrence.—Lower 10 feet of Fremont formation, in Priest Canyon, about 4 miles northwest of Canon City, Colorado.

Repository.—State University of Iowa, 8065.

Ephippiorthoceras sp.
Plate 17, figure 7

The writer has a relatively large specimen which he is referring to *Ephippiorthoceras* but which is so imperfectly preserved that its specific affinities cannot be ascertained. It is a fragmentary internal mold in rather fine-grained pink dolomite which has been exposed to weathering in such a way that only the lateral zones and a portion of either the dorsal or ventral side are preserved. The specimen is 104 mm. in length, and represents parts of 11 camerae. It is subcircular in cross-section, and expands from a diameter of 35 mm. at the adapical end to a diameter of 45 mm. at the adoral end. This indicates an apical angle of approximately 6 degrees. The camerae are subequal in length, slightly more than five occurring in a distance equivalent to the maximum diameter of the conch. The sutures form prominent lateral lobes whose "troughs" are 10 mm. apicad of the "crests" of the saddles on the adjacent dorsal or ventral side. At the adapical end of the specimen there is a slight, subcentral, lunate depression which is approximately 6 mm. in diameter, and which may represent the siphuncle.

Discussion.—The configuration of this specimen falls within the fairly broad limits of *E. formosum* (Billings), but does not show any of the lengthwise curvature apparently typical of that species.

Occurrence.—Base of massive member, Fremont formation, in unnamed valley tributary to Wilson Creek, about sec. 25, T. 17 S., R. 71 W., Fremont County, Colorado.

Repository.—State University of Iowa, 8066.

Kionoceras sp.
Plate 18, figure 2

One small fragment of an orthoceracone, which has prominent longitudinal ridges and faint transverse striae occurs in the writer's Fremont collection, and is being placed in *Kionoceras*. The specimen, which apparently represents a portion of a body chamber, is 12 mm. in length, and is broadly elliptical in cross-section, having diameters of 5.5 mm. and 9 mm. at the adoral end. The surface of the mold preserves prominent longitudinal ribs which are sharp-edged, and are spaced 1.5 mm. apart. The spaces between the ridges are broad, and slightly concave. Faint transverse striae are preserved on much of the specimen, and, at fairly regular intervals of about 2 mm., these are punctuated by more prominent raised lines which form slight nodes where they intersect the longitudinal ridges.

Occurrence.—Lower portion of Fremont formation, near Canon City, Colorado. Specimen from Colorado School of Mines Collection. Exact locality not known.

Repository.—State University of Iowa, 8067.

Lambeoceras sp.
Plate 16, figure 4; text-figure 1C

The collection at hand contains an imperfectly preserved internal mold of a small portion of a phragmocone, which shows both the siphuncle and the characteristic transverse section of *Lambeoceras*. The over-all length of the specimen is 24 mm., and at the adapical end, dorso-ventral and lateral diameters are approximately 25 mm. and 55 mm. respectively. The shape of the cross-section is shown in text-figure 1C, and it appears that the dorsal and ventral sides are almost equally convex. The camerae are relatively short, being about one-eleventh as long as wide. The sutures form broad ventral, and presumably dorsal lobes, separated by saddles on the angular lateral margins.

The siphuncle is ventral, and is located 2 mm. from the venter at the adoral end of the specimen. At this place, its diameter is slightly less than 3 mm. The segments of the siphuncle expand within the camerae, and have a subspherical shape.

Discussion.—As the numerous existing species of *Lambeoceras* are differentiated largely on the basis of size, shape, and particularly rate of adoral expansion, the specimen at hand can hardly be placed in a specific category. It is similar, however, to forms from the Stewartville and Bighorn formations described by Foerste as *L. confertum*, differing from these specimens primarily in that the venter is not as noticeably flattened.

Occurrence.—Lower member of Fremont formation, in unnamed valley tributary to Wilson Creek, about sec. 25, T. 17 S., R. 71 W., Fremont County, Colorado.

Repository.—State University of Iowa, 8068.

PROBILLINGSITES KESSLERI Sweet, n. sp.
Plate 16, figures 1, 2

This species is based on a single specimen, which is the largest representative of *Probillingsites* yet described. It is a well-preserved, slightly distorted internal mold 254 mm. in length, which preserves part of the shell and represents the mature portion of a conch which is unusually large for this genus. The phragmocone is gibbous; the body chamber is slightly concave to nearly straight dorsally, and it contracts regularly to the aperture laterally. The conch expands orad to maximum dorso-ventral diameters of 118 mm. and 143 mm., 120 mm. above the adapical end. Corresponding apertural diameters are 98 mm. and 139 mm. respectively. The conch is curved, and the venter is convex throughout its length. The sides are also convex, reaching a maximum convexity 16 mm. above the adapical end of the body chamber.

The septum of truncation blends in with the conch, but its position is indicated by a low, rounded ridge which can be traced across the dorsum and one of the lateral zones onto the ventrolateral margin of the conch. It is subhemispherical in shape, and its suture is oblique, sloping from 45 mm. orad of the adapical end on the dorsum to 17 mm. orad of the adapical end on the venter. The succeeding four sutures are slightly less oblique than that of the adapical septum, and are somewhat closer together laterally than they are on the dorsum. The suture immediately orad of the septum of truncation is 76 mm. from the adapical end on the dorsum, and 53 mm. from it on the ventrolateral margin. The next suture is 13 mm. orad of the previous one dorsally, and 14 mm. from it ventrolaterally, but the two are only 11 mm. apart laterally. The two sutures which succeed the last described are close together. The adapical one is 10 mm. orad of the one which precedes it on the dorsum, and 11 mm. orad of it ventrolaterally. Only 5 mm. separate these two sutures on the dorsum, and 4 mm. on the ventrolateral

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EXPLANATION OF PLATE 17

FIGS. *1, 2*—*Actinoceras* sp. Lateral and ventral views of an incomplete internal mold which is broken, exposing the siphuncle, ×1; from massive dolomite member, Fremont formation, in unnamed valley tributary to Wilson Creek, Fremont County, Colorado. (p. 75)

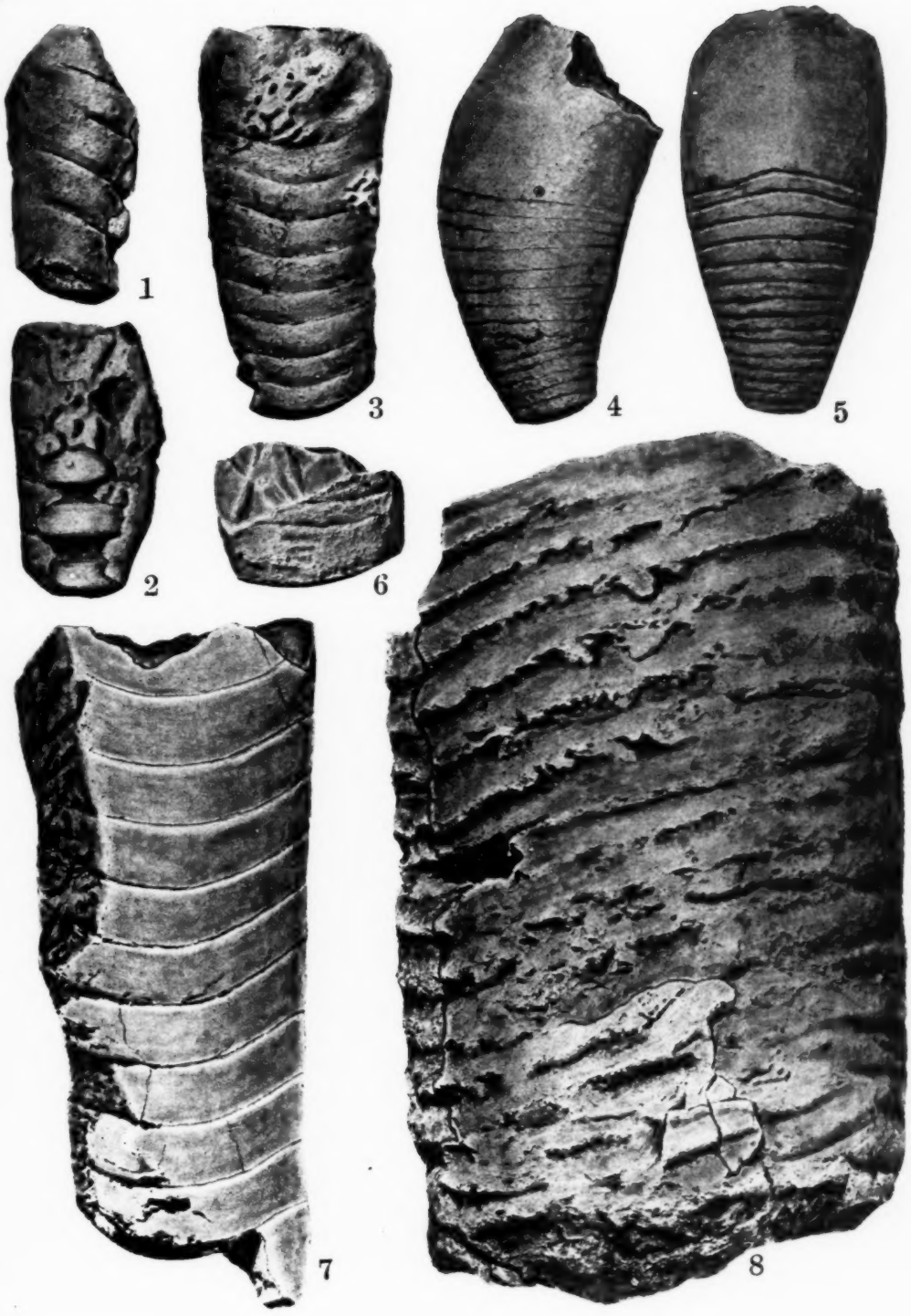
3—*Ephippiorthoceras formosum* (Billings). Lateral view of an internal mold, ×1; from base of massive dolomite member of Fremont formation, in Priest Canyon, Fremont County, Colorado. (p. 78)

4, 5—*Beloitoceras accultum* Foerste. Lateral and ventral views of an internal mold, ×1; from base of massive dolomite member, Fremont formation, about 2 miles northwest of Canon City, Colorado. (p. 75)

6—*Allumettoceras* sp. Ventral view of an incomplete internal mold, ×2; from base of Priest Canyon member, Fremont formation, in Priest Canyon, Fremont County, Colorado. (p. 82)

7—*Ephippiorthoceras* sp. Lateral view of an internal mold, ×1; from base of massive dolomite member, Fremont formation, in unnamed valley tributary to Wilson Creek, Fremont County, Colorado. (p. 79)

8—*Cyclendoceras cylindricum* Miller. Lateral view of an incomplete internal mold with siphuncle exposed along left margin, ×1; from base of massive dolomite member, Fremont formation, about 2 miles northwest of Canon City, Colorado. (p. 77)



Sweet, Ordovician cephalopods, Colorado

Sweet, Ordovician cephalopods, Colorado
Sweet, Cephalopods, Wyoming and Utah

margin. Slightly ventrad of the lateral part of the conch, these two sutures are only 2 mm. apart.

The aperture is dorsally inclined, and shows no trace of a hyponomic sinus. The siphuncle is ventral, circular in outline, and is 9 mm. in diameter where it passes through the septum of truncation.

Discussion.—The unusually large size of this specimen differentiates it readily from all previously described species of *Probillingsites*. In dimensional ratios it is probably closest to *P. lebanonensis* Flower from the Arnheim formation of Kentucky. However, *P. kessleri* is regularly convex throughout its length, while the body chamber of *P. lebanonensis* is "tubular" in its upper half. Furthermore, the sutures of *P. lebanonensis* are more strongly inclined than are those of the Fremont specimen. The curvature of the sutures, and their departure from parallelism, suggests that *P. kessleri* is more closely allied to species described from the Upper Ordovician than to those known from older horizons, in which the sutures are nearly parallel, and generally transverse.

Occurrence.—Basal portion of massive dolomite member, Fremont formation, in the Colorado Fuel and Iron Company Quarry, about 2 miles northwest of Canon City, Colorado.

Repository.—Canon City Municipal Museum, Amick Wing, 77.

SPYROCERAS sp.
Plate 16, figure 3

This specimen is an internal mold 83 mm. in length to which some of the shell remains attached; 21 mm. of the length represents seven and one-half camerae of the phragmocone, whereas the remaining 62 mm. represents body chamber. The conch, which is slightly compressed, expands very gradually from diameters of 23 mm. and 20 mm. at the adapical end of the specimen, to corresponding diameters of 30 mm. and 27 mm. at the adoral end. The sutures are evenly spaced and are directly transverse to the long axis of the conch.

The surface of the shell bears low, rounded, transverse annulations which are about as wide as the concave interspaces. The annulations are not quite normal to the long axis of the conch, and are slightly sinuous in form. Although their spacing shows a certain amount of variation, they average 8 mm. from crest to crest. In addition to the annulations, the surface of the shell has both transverse and longitudinal lirae, the former of which are the least prominent and are nearly parallel to the annulations. The longitudinal lirae alternate in prominence. That is, between each pair of prominent lirae, there are one or two finer raised lines. No trace of the siphuncle is preserved.

Discussion.—*Spyroceras* is here used in its original broad sense for a group of "longitudinally ridged longicones, which at some stage of their growth are also annulated" (Hyatt, 1884, p. 276). Subdivisions of *Spyroceras* based on the relative position and arrangement of the shell ornamentation appear to be of doubtful value, and other subdivisions require a knowledge of the siphuncular structure not available from the specimen at hand. Consequently, the Fremont form is placed in *Spyroceras* s.l., even though

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EXPLANATION OF PLATE 18

Cephalopods from the Fremont formation of central Colorado

FIG. 2—*Kionoceras* sp. Lateral? view of an incomplete internal mold of part of a body chamber, ×2; from massive dolomite member, Fremont formation, near Canon City, Colorado. (p. 79)

5—*Endoceras* sp. Lateral view of an internal mold, ×½; from base of massive dolomite member, Fremont formation, in Priest Canyon, Fremont County, Colorado. (p. 78)

6—*Cyclendoceras cylindricum* Miller. Ventrolateral view of a large, crushed internal mold of part of a phragmocone, with siphuncle exposed on left, ×½; from base of massive dolomite member, Fremont formation, in Priest Canyon, Fremont County, Colorado. (p. 77)

Some early Paleozoic cephalopods from Wyoming and Utah

FIG. 1—*Cyrtogomphoceras* sp. Dorsal view of an incomplete internal mold, ×½; from Lander sandstone member of Bighorn formation, some 10 miles southwest of Lander, Wyoming. (p. 83)

3, 4—*Huronia vertebralis* Stokes. Incomplete siphuncles of two individuals, ×1; from dark, cherty dolomite near Gettel Playa, Millard County, Utah. (p. 84)

the genotype comes from the Middle Devonian.

Occurrence.—Lower member, Fremont formation, near Canon City, Colorado. Colorado School of Mines Collection. Exact location not known.

Repository.—State University of Iowa, 8069.

ALLUMETTOCERAS sp.
Plate 17, figure 6; text-figure 1A

The only nautiloid in the present collection from the Priest Canyon member of the Fremont formation is an internal mold of a very small portion of a phragmocone which has the characteristic transverse section of *Allumettoceras*. The specimen is 8 mm. in length, and represents nearly three complete camerae. The sutures form broad dorsal and ventral lobes, and narrowly rounded lateral saddles. The dorso-ventral and lateral diameters at the adapical end of the specimen are 8.5 mm. and 12 mm. respectively, and a projection of the lateral outlines indicates that the complete conch expanded rather rapidly. As shown in text-figure 1A, the dorsum is less broadly rounded than the venter; the siphuncle is ventral in position, circular in outline, and 1 mm. from the venter at the adapical end of the specimen. In this section, it has a diameter of 1 mm.

Discussion.—*Allumettoceras* is a fairly widespread genus in the Middle Ordovician of North America, and it has also been reported from typical "arctic" faunas in Baffin Island, Manitoba, and Wyoming. Its occurrence in the Priest Canyon member of the Fremont, with a brachiopod assemblage similar to that of the Richmond Maquoketa shale of Iowa, may well be the highest recorded occurrence of the genus. The genotype, *Tripteroceras paquettense*, comes from Middle Ordovician beds at Paquette Rapids on the border between Ontario and Quebec.

Occurrence.—Priest Canyon member, Fremont formation, in Priest Canyon, about 4 miles northwest of Canon City, Colorado.

Repository.—State University of Iowa. 8070.

MANUSCRIPT RECEIVED APRIL 15, 1954

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JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 1, PP. 83–85, PL. 18 (FIGS. 1, 3, 4), JANUARY 1955

SOME EARLY PALEOZOIC CEPHALOPODS FROM WYOMING AND UTAH

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ABSTRACT—A specimen of *Cyrtogomphoceras* which appears to confirm the endogastric nature of the conch is described from the Ordovician Lander sandstone of western Wyoming. In addition, two siphuncles referable to *Huronia vertebralis* Stokes are described from Silurian rocks lying above *Conchidium*-bearing strata and below the Lone Mountain formation of western Utah. Earlier reports mention only one other Silurian cephalopod from this region.

INTRODUCTION

THE paleontological collections of the State University of Iowa contain an incomplete, undescribed specimen of *Cyrtogomphoceras* which elucidates certain features of the antisiphuncular side of the conch that may be significant in the interpretation of the genus. In addition, Professor Richard W. Rush of the University of Texas has sent in two well-preserved siphuncles, referable to the genus *Huronia*, which he collected from a dark cherty dolomite in the Silurian of western Utah. Only one other Silurian cephalopod has been identified from this region (Kirk in Nolan, 1935), and it is also referable to *Huronia*. The strata from which the present specimens were collected have apparently yielded only one other identifiable fossil, the ubiquitous chain-coral, *Halysites*. Although *Huronia* was based on specimens from the Silurian of Drummond Island, in Lake Huron, representatives of it are known from strata well down in the Upper Ordovician of North America. This, of course, is also true of *Halysites*. However, the presence of the costate pentameroid *Conchidium*, a rather reliable index to the Middle Silurian, in strata below the rocks from which the huronias were collected, indicates that the specimens are Silurian in age, and probably Niagaran.

SYSTEMATIC DESCRIPTIONS

CYTOGOMPHOCERAS sp.
Plate 18, figure 1[1]

This specimen is an internal mold 144 mm. in length, which is moderately well-preserved in medium-grained pink sandstone, and represents the mature portion of a fairly large conch. The dorsal portions of seven camerae are preserved, and the apertural margin of the body chamber is nearly complete. The conch is distinctly curved lengthwise, the dorsum being strongly convex. Near the oral end, where the specimen is almost complete, it appears that its cross-section was nearly circular. The specimen is widest near the junction of the body chamber and the phragmocone, where it has a lateral diameter of approximately 101 mm. Orad of this, it contracts rather uniformly toward the aperture, which has a lateral diameter of about 67 mm.

The body chamber is essentially complete, and its length (measured at right angles to the adoral suture) is 64 mm. It is rather strongly contracted toward the aperture. The apertural margin, which is missing ventrally, is roughly circular in outline, and is smoothly rounded dorsally. The sutures are nearly transverse to the long axis of the conch at the adapical end of the specimen, but adorally they become more steeply inclined dorsad, so that near the junction of the body chamber and the phragmocone they cross the dorsum as broad saddles. The two adoral camerae are shorter than the preceding ones, which indicates that the specimen represents a mature individual. The camerae (with the exception of the upper two) average 13 mm. in length, and the convergence of the sutures toward the venter indicates that the camerae are somewhat shorter on that side. Nothing is known of the siphuncle in this specimen, for the ventral portion of the conch is not preserved.

Discussion.—It has been the general prac-

[1] For explanation of Plate 18, see page 81.

tice to regard the siphuncular side of *Cyrtogomphoceras* as ventral, and, because that side is usually more or less concave, the conch is generally stated to be endogastric. In his earlier writings, Foerste followed this belief, illustrating several specimens which appear to preserve a rather deep hyponomic sinus on the siphuncular margin of the aperture. In his later years, however, Foerste (1935) termed the siphuncular side of the conch ventral, evidently because he thought he recognized an indication, in the growth lines of *C. vicinum*, of a hyponomic sinus on that side. In the specimen at hand, the apertural margin on the antisiphuncular side of the conch, which is well-preserved, is complete, straight, and shows no trace of a sinus; but a sinus is reported to occur on the siphuncular side of similar specimens from the same locality (Miller, 1932). Consequently, it appears that Foerste's original interpretation of the genus was the correct one, and the conch of *Cyrtogomphoceras* should be considered to be endogastric.

The specimen described herein is similar to, although somewhat larger than the holotype of *C. rotundum* Miller, also from the Lander sandstone of Western Wyoming.

Occurrence.—Lander sandstone member of the Bighorn formation, from float on the divide between Squaw Creek and the Middle Fork of the Popo Agie River, some 10 miles southwest of Lander, Wyoming.

Repository.—State University of Iowa, 8071.

HURONIA VERTEBRALIS Stokes
Plate 18, figures 3, 4

Huronia vertebralis STOKES, 1824, in Bigsby, Trans. Geol. Soc. London, 2d ser., vol. 1, pt. 2, p. 202, explanation of pl. 28, figs. 2, 6.
Orthoceras canadense BILLINGS, 1857, Canada Geol. Survey, Rept. of Progress, 1853–1856, pp. 321–328.
Huronia vertebralis HALL, 1851, Rept. on the Geol. of the Lake Superior Land Dist., by Foster and Whitney, pt. 2, p. 221, pl. 34,—— BARRANDE, 1870, Syst. Sil. du Centre Bohême, vol. 2, pl. 436, figs. 5–7.
Huronia bigsbyi BARRANDE, 1877, Syst. Sil. du Centre Bohême, vol. 2, Suppl., pl. 474, figs. 2–4.
?Huronia vertebralis THOMAS, 1915, Proc. Iowa Acad. Sci., vol. 22, pp. 294–296, pl. 33, fig. 1; pl. 24, fig. 5.
Huronia vertebralis FOERSTE, 1924, Contrib. Mus. Geol., Univ. Michigan, vol. 2, p. 46, pl. 5, figs. 1, 5; pl. 4, figs. 2, 3; pl. 11, fig. 2,—— FOERSTE, 1928, Canada Geol. Survey Mem. 154, p. 300,——SHIMER & SHROCK, 1944, Index Fossils of North America, p. 553, pl. 227, fig. 7.

Two rather well-preserved siphuncles from the Silurian of western Utah, one representing four, and the other almost five segments, are being referred to this species. The larger of the two specimens is 80 mm. in length, and represents almost five segments of the siphuncle. These segments have the shape of an inverted pestle, being almost cylindrical in their adapical part, and broadly expanded or nummuloidal in their adoral portion. The segments are subequal in length, each measuring 14 mm. Of this, 7 mm. represents the cylindrical portion of the siphuncle, and 7 mm. the length of the corresponding annulation. The cross-section is approximately circular, being 19 mm. in diameter at the base of the fourth segment orad from the adapical end. This segment expands to a diameter of 25 mm. in the midportion of the superjacent annulation. The entire unit expands very gradually orad, the adapical segment having an estimated diameter of 16 mm. Siphuncular deposits, composed of many radiating, discontinuous, vertical lamellae, intersected by irregularly disposed, curving "tabulae," are exposed at the adoral end of the specimen, where the outer walls have been weathered away. The internal vertical lamellae produce a series of longitudinal lines on the lateral zones.

The smaller specimen is similar to the larger one just described. It is 57 mm. in length, and represents four complete segments of the siphuncle, and part of a fifth. The segments are about 13 mm. in length, this distance being almost equally divided between the adapical uninflated portion and the superjacent annulation. The specimen is circular in section, expanding from a diameter of 16 mm. at the adapical end to a diameter of 21 mm. at the adoral end of the third complete segment. The internal structure of the siphuncle is similar to that of the larger specimen, but more clearly exposed.

Discussion.—*H. vertebralis* is closely similar to *H. bigsbyi*, the type of the genus, but differs from that species in that the annulations occupy a greater proportion of the segment length than is the case with the genotype.

Occurrence.—Dark, cherty dolomite lying

above *Conchidium*-bearing strata, and below the Lone Mountain formation, 1 mile west of the north end of Gettel Playa (NE ¼ sec. 21, T. 21 S., R. 14 W., Millard County, Utah).

Repository.—State University of Iowa, 8072–8073.

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JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 1, PP. 86–101, PLS. 19, 20, 2 TEXT-FIGS., JANUARY 1955

UPPER CAMBRIAN AGNOSTIDAE OF THE EUREKA DISTRICT, NEVADA[1]

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ABSTRACT—The Upper Cambrian Agnostidae from the Eureka district, Nevada, represent eight species assigned to four genera. Five of the species are new: *Geragnostus brevis*, *Lotagnostus obscurus*, *Litagnostus expansus*, *Pseudagnostus convergens*, and *P. laevis*. The eight species belong to three assemblages that are believed to have regional stratigraphic value. These assemblages are late Dresbach and early Franconia, late Franconia (?), and Trempealeau in age.

The ontogeny of *Pseudagnostus communis* (Hall and Whitfield) shows that the expanded posterior portion of the median lobe on the pygidium can be correctly termed a pseudolobe.

Muscle scars for species of *Pseudagnostus* and *Geragnostus* are described and illustrated. The classification of Upper Cambrian agnostids is briefly discussed.

INTRODUCTION

EIGHT species of agnostid trilobites representing four genera have been collected from Upper Cambrian rocks in the Eureka district, Nevada. Three of the species have been described in early reports on the area (Hall and Whitfield, 1877; Walcott, 1884), and five of the species are new. Two of the new species represent genera that have not been reported previously from western North America. The eight species constitute about 15 percent of the specifically identifiable Upper Cambrian trilobites of the Eureka district.

The fossiliferous Upper Cambrian deposits in the Eureka district are placed in the Dunderberg shale and two unnamed units overlying the Dunderberg, which last were viewed as the lower part of the Pogonip limestone. The Upper Cambrian and Lower Ordovician rocks of the Eureka district are reclassified by T. B. Nolan and C. W. Merriam in a stratigraphic report now in preparation. For field use the two post-Dunderberg Upper Cambrian map units, totaling about 650 feet in thickness, were provisionally designated as unit 1 of the Pogonip limestone and unit 2 of the Pogonip limestone in ascending order. As now recognized in the Great Basin the Cambrian-Ordovician boundary is a few feet above the top of unit 2 of the Pogonip. Unit 1 of the Pogonip, about 250 feet thick, is characterized by an alternation of massive limestone beds with thinner sandy or silty limestones. Light- and dark-gray laminated chert is present. Unit 2 of the Pogonip, about 400 feet thick, shows light-colored, thin-bedded, slabby-weathering limestones. Nolan and Merriam (in preparation) propose new names for the above-mentioned post-Dunderberg high Cambrian units and restrict use of Pogonip to overlying strata of Ordovician age.

The agnostid species described in this paper can be grouped into three faunal assemblages. The oldest assemblage, which is associated with non-agnostid trilobites of the post-*Aphelaspis* and *Elvinia* zones of the standard Upper Cambrian sequence, is characterized by *Geragnostus tumidosus* (Hall and Whitfield) and species of *Pseudagnostus*. It ranges throughout the Dunderberg shale and into the lower part of unit 1 of the Pogonip limestone. The lower part of the range of this assemblage is characterized by *Pseudagnostus communis* (Hall and Whitfield), and the upper part is characterized by *Pseudagnostus prolongus* (Hall and Whitfield).

The next younger assemblage, characterized by *Lotagnostus obscurus* Palmer, n. sp., and *Pseudagnostus convergens* Palmer, n. sp., is found in the upper part of Unit 1 of the Pogonip limestone. Associated nonagnostid trilobites are similar to those described by Rasetti (1944) from the *Hungaia magnifica* fauna in boulders of the Levis conglomerate in Quebec. The *H. magnifica* fauna has been thought to be of Trempealeau age (Rasetti, 1945, p. 462; Shaw, 1951, p. 99). However,

[1] Publication authorized by the Director, U. S. Geological Survey.

trilobites from the Eureka district and other areas in Nevada that are comparable to some of the fauna described from Quebec are found immediately above the *Elvinia* fauna of early Franconia age and below beds containing saukiid trilobites of Trempealeau age. This suggests that perhaps the *Hungaia magnifica* fauna is older than suspected. The *Lotagnostus obscurus* assemblage is considered here to be probably Franconia in age.

The youngest assemblage, which is associated with non-agnostid trilobites of definite Trempealeau age, is characterized by *Pseudagnostus laevis* Palmer, n. sp., and *Geragnostus brevis* Palmer, n. sp. It is found in unit 2 of the Pogonip limestone.

REMARKS ON THE CLASSIFICATION OF THE AGNOSTIDAE

Opinions concerning the suprageneric classification of the agnostid trilobites have been expressed principally by Whitehouse (1936), Harrington (1938), and Kobayashi (1939). The classification of the Middle Cambrian agnostids has been reviewed subsequently by Westergård (1946), and the classification of some of the Upper Cambrian agnostids has been discussed by Shaw (1951).

Three general types of agnostids are recognized in the Eureka district: a *Pseudagnostus*-type with a preglabellar median furrow on the cephalon and a pseudolobe on the pygidium; a *Geragnostus*-type, which lacks a preglabellar median furrow and has a nearly parallel-sided axial lobe on the pygidium that is evenly rounded at the rear and does not reach to the border; and an intermediate type characterized by the genus *Lotagnostus*, with a pseudagnostid cephalon and a geragnostid pygidium. These types have been referred by Kobayashi (1939) to the subfamilies Pseudagnostinae, Geragnostinae, and Agnostinae, respectively.

The Pseudagnostinae (Whitehouse, 1936, p. 97, as Pseudagnostidae) originally included *Pseudagnostus* Jaekel, *Plethagnostus* Clark, and *Rhaptagnostus* Whitehouse. The latter two genera were considered to be synonyms of *Pseudagnostus* by Kobayashi (1939). His views have been supported by Rasetti (1944, p. 234) for *Plethagnostus* and Palmer (1954) for *Rhaptagnostus*.

Litagnostus Rasetti is a smooth agnostid of the type that has been placed usually in the Phalacrominae. The specimen of *Litagnostus* from the Eureka district shows, when coated with magnesium oxide, an outline of the axial lobe of the pygidium that is identical to that of *Pseudagnostus*. The writer considers *Litagnostus* to be a small member of the Pseudagnostinae.

Geragnostus and *Lotagnostus*, representing the Geragnostinae and Agnostinae of Kobayashi, have certain morphologic similarities, particularly in the pygidium, which suggest that they may be closely related and that possibly they should be included in the same subfamily. Pygidia of each genus have a straight-sided axial lobe that is evenly rounded at the rear and does not reach the marginal furrow. The segmentation of the axial lobes is nearly identical. The principal differences are in the degree of development of furrows on the dorsal surface of the test, the relative relief of the axial lobes and of the pygidia, and the size of the adult forms. The cephalons differ by the presence (*Lotagnostus*) or absence (*Geragnostus*) of a preglabellar median furrow and by details of outline and relief of the glabella.

In this paper, *Geragnostus* and *Lotagnostus* are assigned to the Geragnostinae. No representatives of the Agnostinae are recognized. Thus, the Upper Cambrian agnostids from the Eureka District are considered to represent two distinct groups, designated as subfamilies, that differ in the outline of the axial lobe of the pygidium. Each group consists of two genera whose affinities are indicated in the axial lobe of the pygidium and whose differences are in the degree of development of furrows on the dorsal surface, the relative relief of the axial regions, and details of the peripheral parts of the test.

SYSTEMATIC PALEONTOLOGY

Terminology.—A standard terminology for describing the dorsal features of the agnostid cephalon and pygidium has not been consistently used by paleontologists dealing with these trilobites. There is general agreement concerning the terms to be applied to the more prominent features, but various terms have been applied to some of the smaller peripheral and axial features. The terms used in this paper for describing

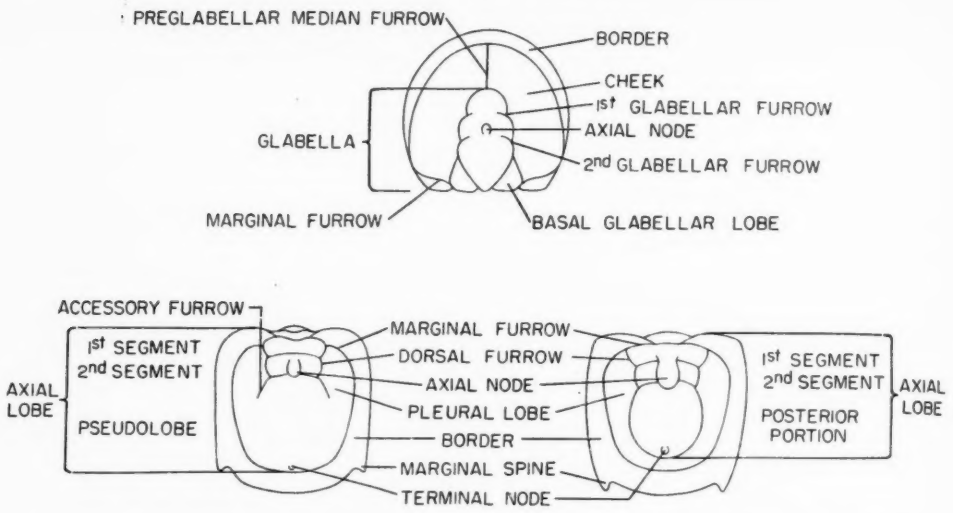

FIG. 1—Terminology for describing the cephalon and pygidium of an agnostid trilobite.

the dorsal features of agnostid cephalons and pygidia are shown on figure 1.

Measurements.—Measurements of individual specimens for the quantitative determinations were made to the nearest 0.05 mm. using a micrometer eyepiece attachment on a Spencer binocular microscope. Dimensions mentioned in the text are to the nearest half millimeter unless otherwise indicated.

Repository.—All the specimens figured in this paper except the pygidium of *Pseudagnostus communis* (Hall and Whitfield) (pl. 20, fig. 11) are the property of the United States National Museum and are deposited in the collections of that institution in Washington, D. C. The cited pygidium of *P. communis* is in the collections of the Bureau of Economic Geology of the University of Texas in Austin, Texas.

Family AGNOSTIDAE McCoy, 1846
Subfamily GERAGNOSTINAE Howell, 1935

Diagnosis.—Agnostidae with preglabellar median furrow on cephalon either present or absent.

Pygidium with axial lobe nearly parallel sided, evenly rounded at rear, not extended to border. Anterior pair of transverse axial furrows often curved forward to cut anterior margin making anterior segment of axial lobe appear transversely trilobate. Marginal spines usually present.

Genus GERAGNOSTUS Howell, 1935

Geragnostus HOWELL, 1935, p. 231, ——, SHAW, 1951, p. 110, ——, PALMER, 1954, p. 719.

Type species.—*Agnostus sidenbladhi* Linnarsson, 1869, p. 82, pl. 2, figs. 60, 61.

Diagnosis.—Cephalon with bilobed glabella and no median longitudinal preglabellar furrow; simple basal glabellar lobes present.

Pygidium with prominent, longitudinally trilobate, distinctly defined, nearly parallel-sided axial lobe that is rounded posteriorly and that does not reach to the border. Marginal spines present.

Discussion.—This genus is represented in the Eureka district by two species, *G. tumidosus* (Hall and Whitfield) and *G. brevis* Palmer, n. sp. These species differ from the species of *Geragnostus* described from eastern North America and from localities outside of this continent by lacking distinct trilobation of the anterior segment of the axial lobe of the pygidium. For this reason, they are not placed in any of the established subgenera of *Geragnostus*. This type of geragnostid is known at present only from Nevada and central Texas (Palmer, 1954, p. 719).

GERAGNOSTUS TUMIDOSUS (Hall and Whitfield)

Plate 19, figures 3, 4; Plate 20, figures 1–3, 12, 15

Agnostus tumidosus HALL and WHITFIELD, 1877, p. 231, pl. 1, fig. 32.
Geragnostus cf. *G. tumidosus* (Hall and Whitfield) PALMER, 1954, p. 719.

Diagnosis.—Cephalon with anterior lobe of glabella narrower than posterior lobe.

Axial lobe of pygidium extends nearly to border; anterior segment not trilobate; combined length of the two anterior segments (exclusive of articulating ring) less than length of posterior portion; axial node confined to second segment.

Description.—Cephalon about as wide as long, somewhat expanded and strongly rounded anteriorly, moderately arched transversely and longitudinally. Glabella well defined by dorsal furrow, tapered forward and strongly rounded in front. Length about two-thirds, width about one-third that of the cephalon. Anterior lobe of glabella separated from remainder of the glabella by distinct transverse furrow. Posterior lobe elevated above the cheeks, highest behind its midlength; distinctly broader than the anterior lobe. No distinct axial node. Basal lobes subtriangular in outline and undivided. Cheeks undivided, slope gently away from glabella toward anterior margin and steeply away toward posterolateral margin. Border narrowest at posterolateral margin and widest at anterolateral margin. Surface of the cephalon smooth.

Pygidium slightly wider than long, nearly parallel sided, broadly rounded posteriorly and strongly arched transversely and longitudinally. Axial lobe well defined, not extended to the border. Length about eight-tenths, and width about six-tenths that of pygidium. Anterior third, behind well-defined articulating ring, partially divided into subequal parts by two pairs of distinct furrows extending in from dorsal furrow. Anterior pair of furrows extends inward and slightly forward about one-third width of axial lobe. Posterior pair extends inward to posterolateral margins of a prominent axial node that merges anteriorly with surface of axial lobe. Posterior portion of axial lobe is slightly expanded and strongly rounded behind. Pleural platforms downsloping from axial lobe to border. Border moderately wide, marginal spines short, sharp, located about opposite posterior end of axial lobe. Surface smooth.

Discussion.—*A. tumidosus* Hall and Whitfield was placed in *Homagnostus* Howell by Kobaysahi (1939, p. 162). Howell's original diagnosis of *Homagnostus* noted the presence of a preglabellar median furrow on the cephalon. This feature was emphasized by Lochman and Duncan (1944, p. 140) as distinctive of the genus. The cephalons of *A. tumidosus* Hall and Whitfield from the Eureka district show no evidence of a preglabellar median furrow and therefore cannot belong to *Homagnostus* as presently defined. The combined features of the cephalons and associated pygidia seem to characterize a species of *Geragnostus* having a relatively large posterior glabellar lobe that lacks an axial node, and a relatively long axial lobe on the pygidium. On most pygidia the anterior pair of furrows on the axial lobe does not curve forward to the anterior margin.

This species differs from *G. brevis* Palmer, n. sp., by having a relatively longer axial lobe on the pygidium and by having the posterior portion of the axial lobe slightly expanded rather than tapered posteriorly.

Quantitative variation.—Regressions were calculated for the length versus width of the cephalon for 15 specimens and the length of the axial lobe versus total length of the pygidium for 13 specimens for purposes of comparing *G. tumidosus* (Hall and Whitfield) with *G. brevis* Palmer, n. sp. The pertinent statistical information, regression lines, and 2 S_Y limits for *G. tumidosus* and plotted data for both species are shown on figure 2. The calculations indicate that the axial lobe of the pygidium of *G. brevis* is significantly shorter than that of *G. tumidosus* and that the apparent narrowness of the cephalon of *G. brevis* is probably not significant. The data used in the statistical calculations are given on table 1. Divisions are in millimeters.

Qualitative variation.—The longitudinal profile is the only feature of the cephalon that varies. Some specimens have an evenly curved profile; others have a distinct angularity at about the midlength of the posterior glabellar lobe, and the anterior portion

TABLE 1.—DATA USED FOR STATISTICAL CALCULATIONS AND COMPARISONS SHOWN ON TEXT-FIGURE 2

Cephalons	*G. brevis*		*G. tumidosus*															
Collection no. or type designation	56 (OS)	803 (CO)	Hol.	788 (CO)	824 (CO)	872 (CO)		952 (CO)	953 (CO)			955 (CO)						
Width (mm.)	2.20	1.15	2.75	1.90	1.60	2.25	2.00	1.35	2.40	3.00	0.90	1.70	2.10	2.00	1.45	1.90	1.50	
Length (mm.)	2.30	1.25	2.60	1.80	1.60	2.25	2.00	1.35	2.25	3.00	0.80	1.75	2.05	1.95	1.45	1.30	1.55	

Pygidia	*G. brevis*				*G. tumidosus*													
Collection no. or type designation	56 (OS)	803 (CO) Hol.	815 (CO)	1364 (CO)	788 (CO)	872 (CO)				953 (CO)					955 (CO)			
Length (mm.)	1.75	1.95	2.10	1.60	1.90	2.10	1.80	2.25	2.35	2.55	2.60	1.60	2.00	1.70	1.80	2.25	1.20	
Length of axial lobe (mm.)	1.30	1.45	1.50	1.20	1.60	1.75	1.45	1.95	2.05	2.15	2.10	1.35	1.70	1.45	1.45	1.80	0.90	

of the glabellar appears slightly depressed.

Most of the pygidia are consistent in their observable characteristics, differing only in the relative strength of the dorsal and axial furrows. These differences seem to be due primarily to the variation in quality of preservation of the specimens. Two specimens differ from the "norm" (pl. 20, figs. 2, 3). One has the axial node well defined on the first axial segment so that the first pair of transverse furrows appear to curve forward to the anterior margin, outlining a well-defined pair of lateral lobes. The other specimen has the axial node extended about

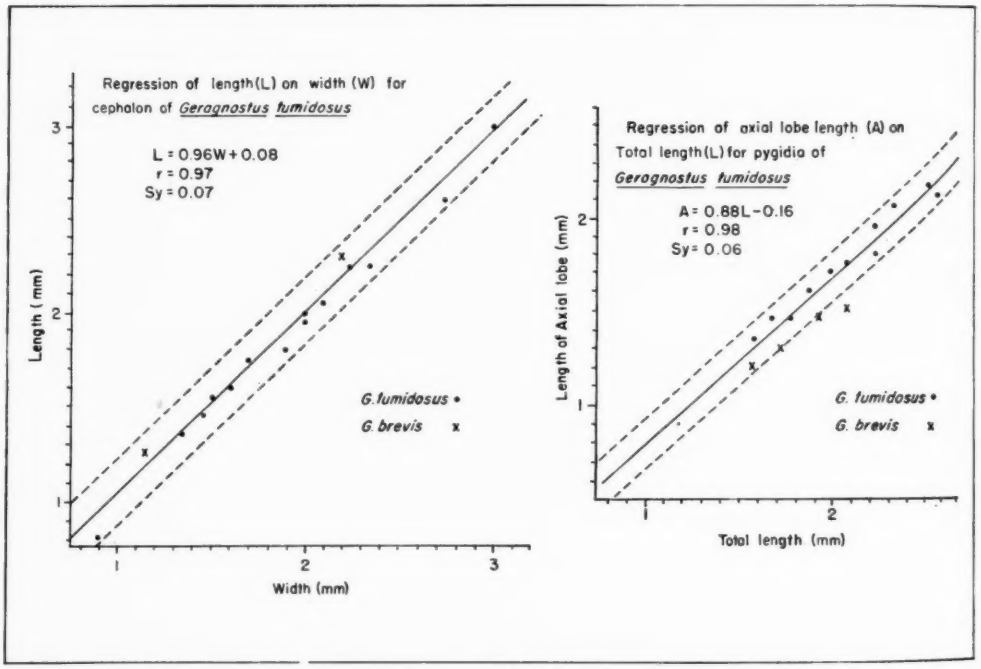
Regression of length(L) on width (W) for cephalon of Geragnostus tumidosus
L = 0.96W + 0.08
r = 0.97
Sy = 0.07
Length (mm)
Width (mm)
G. tumidosus •
G. brevis x
Regression of axial lobe length (A) on Total length(L) for pygidia of Geragnostus tumidosus
A = 0.88L - 0.16
r = 0.98
Sy = 0.06
Length of Axial lobe (mm)
Total length (mm)
G. tumidosus •
G. brevis x

FIG. 2—Comparison of specimens of *Geragnostus brevis* Palmer, n. sp., with regressions for *G. tumidosus* (Hall and Whitfield). r = coefficient of regression, S_y = standard deviation from the regression. Dashed lines indicate $\pm 2\ S_y$ limits.

half its observable length posterior to the second transverse axial furrow.

Special features.—An immature pygidium 0.75 mm. in length shows partially developed thoracic segments and traces of two transverse furrows on the axial lobe (pl. 20, fig. 1). The anterior furrow trace is continuous across the lobe in contrast to later stages in development in which it is present only at the sides of the axial lobe and in which the inner ends curve forward.

A unique exfoliated pygidium shows traces of three pairs of depressions on the axial lobe adjacent to the median node (pl. 20, figs. 12, 15). These are interpreted as muscle scars. The anterior pair of scars is located slightly posterior to the midlength of the first segment of the axial lobe; each scar is transversely elongate in outline, and the long dimension is about equal to a fifth the width of the axial lobe. The middle pair of scars is located on the midlength of the second axial segment; each scar is approximately circular in outline with its diameter about equal to half the width of the axial node. The posterior pair of scars is located on the front part of the posterior portion of the axial lobe; each scar is comparable in size and shape to the scars on the preceding segment. A small median depression is present near the end of the posterior portion of the axial lobe. It seems to represent a thickening of the test at that point, but its significance is not understood.

Occurrence.—Dunderberg shale, U.S.G.S. (CO) collections 788, 824, 864, 872, 873, 952, 953, 954, 955; Pogonip limestone—Unit 1. U.S.G.S. (CO) collection 956.

Figured specimens.—

		Length (mm.)
holotype cephalon,	USNM 24558	2.5
pygidium,	USNM 123553	2
pygidium,	USNM 123554	2
pygidium,	USNM 123555a	2
pygidium,	USNM 123555b	2.5
pygidium,	USNM 123555c	0.75

GERAGNOSTUS BREVIS Palmer, n. sp.
Plate 19, figures 1, 2

Diagnosis.—Cephalon like that of *G. tumidosus* (Hall and Whitfield).

Pygidium with axial lobe subquadrate in outline, tapered slightly posteriorly, somewhat shorter than that of *G. tumidosus*; like that species in all other respects.

Discussion.—This species differs from all others assigned to the genus except *G. tumidosus* by lacking distinct trilobation of the anterior segment of the axial lobe on the pygidium. It differs from *G. tumidosus* by having a relatively shorter axial lobe on the pygidium and by having the posterior portion of the axial lobe slightly tapered rather than slightly expanded posteriorly.

Comparisons of the width versus length of two cephalons and the length of the axial lobe versus total length of four pygidia with the regressions for these characters for *G. tumidosus* are shown on figure 2. The calculations indicate that the axial lobe of this species is significantly shorter than that of *G. tumidosus* .

Occurrence.—Poponip limestone, unit 2. U.S.G.S. (CO) collections 803, 815, 1364; U.S.G.S. (OS) collection 56.

Figured specimens.—

		Length (mm.)
holotype pygidium	USNM 123552	2
cephalon	USNM 123551	1

Genus LOTAGNOSTUS Whitehouse, 1936

Lotagnostus WHITEHOUSE, 1936, p. 101,—— KOBAYASHI, 1939, p. 164.

Type species.—*Agnostus trisectus* Salter, 1864, p. 10, pl. 1, fig. 11.

Diagnosis.—Cephalon with distinct border. Glabella tapered forward, trilobate; axial node on posterior lobe. Preglabellar median furrow present, basal glabellar lobes relatively large, undivided. Cheeks of many specimens have reticulate pattern of shallow furrows.

Pygidium with a distinct border and a pair of marginal spines. Axial lobe tapered posteriorly, not extended to border; consists of two anterior segments and a posterior portion. Each segment and posterior portion usually trilobate. Pleural platforms of many specimens have a reticulate pattern of shallow furrows.

Discussion.—This is the first record of *Lotagnostus* from western North America. The genus has also been reported from Upper Cambrian rocks of Sweden, Great Britain, and China, as well as from Nova Scotia and Quebec in eastern North America.

LOTAGNOSTUS OBSCURUS Palmer, n. sp.
Plate 19, figures 5–7, 10

Description.—Cephalon tapered slightly forward, moderately arched transversely and longitudinally, bluntly rounded at front. Glabella trilobate, bluntly rounded anteriorly, length about two-thirds that of cephalon. All features on dorsal surface outlined by shallow furrows and hardly elevated above cheeks. Faint reticulations are visible on the cheeks of some specimens.

Pygidium tapered slightly posteriorly, moderately to strongly arched transversely and moderately arched longitudinally. Margin evenly rounded at rear. Small marginal spines present. Axial lobe consists of two trilobed anterior segments and a posterior portion. Small terminal node present. Length of axial lobe about three-fourths that of pygidium. All features on dorsal surface of test outlined by shallow furrows. Axial lobe hardly elevated above pleural lobes. Shallow reticulate furrows are visible on the pleural lobes of some specimens.

Discussion.—This species differs from all others assigned to the genus in the shallow nature of the furrows on the dorsal part of the test and in the general lack of relief of the axial region. Cephalons are superficially similar to those of *Pseudognostus prolongus* (Hall and Whitfield) and *P. convergens* Palmer, n. sp., differing principally by having the axial node situated on the posterior glabellar lobe instead of the middle lobe.

Most of the observable variation between specimens is in the degree of development of the furrows. All furrows are more distinctly developed on exfoliated specimens. Two cephalons, both exfoliated, have shallow reticulate furrows on the cheeks. One pygidium (pl. 19, fig. 10) with especially prominent furrows shows a trace of the trilobation of the posterior portion of the axial lobe that is characteristic of most other species of *Lotagnostus*.

Occurrence.—Pogonip limestone, unit 1. U.S.G.S. (CO) collections 790, 807?, 826, 827, 882?.

Figured specimens.—

		Length (mm.)
holotype pygidium,	USNM 123556	6
cephalon,	USNM 123557a	6
cephalon,	USNM 123557b	5.5
pygidium,	USNM 123557c	5

Subfamily PSEUDAGNOSTINAE Whitehouse, 1936

Diagnosis.—Agnostidae with preglabellar median furrow on cephalon usually present.

Pygidium with only first two segments of axial lobe defined on all species by the dorsal furrows. Posteriorly expanded pseudolobe always present, reaching to marginal furrow. It may or may not be defined by accessory furrows. Marginal spines usually present.

Genus LITAGNOSTUS Rasetti, 1944

Litagnostus RASETTI, 1944, p. 234,——SHAW, 1951, p. 113.

Type species.—*Litagnostus levisensis* Rasetti, 1944, p. 235, pl. 36, fig. 5, 6.

Diagnosis.—"Agnostids with both shields presenting an extremely simple structure. Cephalon without a defined glabella, faintly rimmed. Pygidium without a defined rachis, with a wider rim than the cephalon. Small median tubercules may be present on either shield." Rasetti, 1944, p. 234.

Discussion.—*L. expansus* Palmer, n. sp., described below, provides evidence to show that this genus has close affinities to *Pseudagnostus*. It is superficially similar to some smooth agnostids and emphasizes the possible artificial nature of the suprageneric categories of agnostids that are based mostly on the lack of development of furrows on the outer surface of the test.

The pygidium of *L. expansus*, when painted with dilute india ink and coated lightly with magnesium oxide, shows a faint outline of the anterior third of the axial lobe. A postaxial median node, adjacent to the marginal furrow is also present and the border behind the node is slightly depressed, much like the pygidium of *Pseudagnostus laevis* Palmer, n. sp., with which the species is associated. Deepening of all furrows on the pygidium would result in a typical pseudagnostid appearance.

LITAGNOSTUS EXPANSUS Palmer, n. sp.
Plate 19, figure 13

Description.—Cephalon and thorax not known.

Pygidium expanded backward, moderately arched transversely—especially toward front—gently arched longitudinally,

broadly and evenly rounded posteriorly. Marginal spines absent. Anterior portion of axial lobe visible when specimens are coated with magnesium oxide. Posterior lobe or pseudolobe not visible. Border distinct along posterior margin, gradually merges with pleural platforms toward anterolateral margins. Without a magnesium oxide coating, pygidium appears smooth except for two low median nodes—one on the anterior portion and the other adjacent to the border.

Discussion.—The relations of this species to *Pseudagnostus* are discussed under the genus. The species differs from other members of *Litagnostus* by having a postaxial median node and a posteriorly depressed border on the pygidium. This is the first record of a species of *Litagnostus* outside of the northern Appalachian region.

Because only a single pygidium is known for this species, observations of intraspecific variation cannot be made. The specimen has the outer surface of the test preserved. Exfoliated forms will probably show more clearly the shallow furrows in the axial region.

Occurrence.—Pogonip limestone, unit 2. U.S.G.S. (CO) collection 803.

Figured specimen.—

	Length (mm.)
holotype pygidium, USNM 123558	2.5

Genus PSEUDAGNOSTUS Jaekel, 1909

Pseudagnostus JAEKEL, 1909, p. 400,——KOBAYASHI, 1935b, p. 107; 1937, p. 451; 1939, p. 157,——SHIMER and SHROCK, 1944, p. 601,——SHAW, 1951, p. 112,——PALMER, 1954, p. 719.
Rhaptagnostus WHITEHOUSE, 1936, p. 97.
Plethagnostus CLARK, 1923, p. 124; 1924, p. 16.

Type species.—*Agnostus cyclopyge* Tullberg, 1880, p. 26.

Diagnosis.—Cephalon with trilobed glabella and a median longitudinal preglabellar furrow; simple basal glabellar lobes present.

Pygidium with anterior third of axial lobe defined by subparallel dorsal furrows; pseudolobe moderately well to poorly defined by accessory furrows that may disappear posterolaterally so that the pseudolobe merges with the pleural lobes. Marginal spines usually present.

Discussion.—One of the principal points of disagreement concerning the morphology of *Pseudagnostus* has been the nature of the expanded posterior portion of the median lobe of the pygidium. Kobayashi (1935b, p. 108) claimed that the posterior portion of the median lobe is a pseudolobe and the furrow partially outlining it should be termed the "diagonal accessory furrow." A similar argument was presented by Whitehouse (1936, pp. 97, 98). Troedsson (1937, p. 24) disagreed with Kobayashi and Whitehouse and believed that the posterior portion of the medial lobe is truly homologous to the normally tapered axial lobe of other agnostids. In an earlier paper (Palmer, 1954, p. 720) the writer, after studying the disposition of muscle scars on a well-preserved pygidium from central Texas (figured here, pl. 20, fig. 11), supported the views of Troedsson. However, a growth series of *P. communis* (Hall and Whitfield) from a limestone in the Dunderberg shale now provides proof that Kobayashi's interpretation is essentially correct.

A single piece of dark limestone, approximately $2 \times 4 \times \frac{1}{2}$ inches, contains pygidia of *P. communis* ranging from 0.5 mm. to 3 mm. in length. Specimens representing the developmental stages II, IV, and V of Barrande (1852, p. 266) are present. The smallest specimen (0.5 mm. in length) has both thoracic segments still fused to the pygidium. The axial lobe tapers to a point posteriorly, and there is a broad, shallow depression between it and the marginal border. Marginal spines are already present in this stage. Two specimens (0.7 and 0.75 mm. in length) represent a stage of development intermediate between the immature form described above and typical adult forms. The axial lobe of each of the specimens at first glance appears to be expanded posteriorly; however, a light coat of magnesium oxide shows shallow dorsal furrows marking the faint triangular outline of the axial lobe within a larger expanded area defined by more prominent furrows. This seems to demonstrate conclusively that the posterior portion of the median lobe of *Pseudagnostus* should be designated as a pesudolobe outlined by an accessory furrow. In the larger stages, the outline of the axial lobe within the pseudolobe is completely effaced. On many specimens, the accessory furrows become progressively shallower backward

from the anterior portion of the axial lobe, so that the pseudolobe and the pleural lobes are confluent towards the rear of the pygidium, hence the term "diagonal accessory furrow" by Kobayashi (1935b). The successive developmental stages of the pygidium of *P. communis* (Hall and Whitfield) upon which the above discussion is based are illustrated on plate 20, figures 4–10.

PSEUDAGNOSTUS COMMUNIS (Hall and Whitfield)
Plate 19, figures 16, 19–21; Plate 20, figures 4–11, 14

Agnostus communis HALL and WHITFIELD, 1877, p. 228, pl. 1, figs. 28, 29.
Agnostus neon HALL and WHITFIELD, 1877, p. 229, pl. 1, figs. 26, 27.

Description.—Cephalon somewhat expanded forward, strongly rounded at anterolateral corners, gently rounded across front, moderately arched transversely and longitudinally, width and length about equal. Glabella well defined by dorsal furrow, tapered slightly forward, strongly rounded in front; length about seven-tenths and width about three-tenths that of the cephalon. Shallow first glabellar furrow separates the anterior third from the remainder of glabella. Shallow indentations marking the second glabellar forrow are present on each side of middle of glabella about opposite poorly defined axial node. Basal lobes subtriangular, undivided. Preglabellar median furrow extends from front of glabella to border. Cheeks slope gently away from glabella towards anterior margin and steeply away towards posterolateral margin. Border narrowest at posterolateral corners of cephalon, expanded slightly forward. Surface smooth.

Pygidium nearly parallel sided, broadly rounded posteriorly, moderately arched transversely and longitudinally, width slightly greater than length. Anterior third of axial lobe nearly parallel sided, slightly more than a third the width of pygidium, delineated posteriorly by a shallow transverse furrow. Prominent axial node situated just anterior to this furrow. Anterior half of pseudolobe moderately well defined by accessory furrows. Pleural platforms downsloping from axial lobe to border. Marginal furrow broad and shallow. Border moderately wide, bearing pair of short, sharp marginal spines about a fifth the length of pygidium from posterior end. Surface smooth.

Discussion.—This species differs from *P. prolongus* (Hall and Whitfield) and *P. laevis* Palmer, n. sp., by having well-developed furrows outlining the glabella and most of the axial lobe of the pygidium. *P. neon* (Hall and Whitfield), represented only by an exfoliated cephalon and pygidium, is tentatively considered to be a synonym of *P. communis* (Hall and Whitfield). Certain identification cannot be made without more knowledge concerning the outer surface of the test of *P. neon*. *P. communis* differs from *P. cyclopyge* (Tullberg), the type species, by having a more quadrate outline to the cephalon and pygidium and more prominent furrows outlining the glabella and the axial lobe on the pygidium. The preglabellar median furrow of *P. communis* is usually shallower than the dorsal furrow in contrast to that of *P. cyclopyge*, which is relatively deeper than the dorsal furrow on the specimens examined.

Most of the observable variation in appearance of the cephala and pygidia is caused by exfoliation. Furrows are more distinct on internal molds than on the outer surface of the test. Internal molds of some pygidia show traces of the points of muscle attachment and paired scars on the axial lobe, illustrated on plate 20, figure 11, from a specimen of this species in the Riley formation of central Texas.

Special features.—At least three developmental stages of *Pseudognostus communis* can be recognized and compared to the stages described by Barrande (1852, p. 266) for Middle Cambrian agnostids. These are: (1) an immature stage in which the pygidium and both thoracic segments are fused into a single shield and a well-defined axial lobe tapers posteriorly (Barrande stages I, II); (2) an early mature stage in which the pygidium has shed the thoracic segments and the axial lobe is poorly defined within the better defined, expanded pseudolobe (Barrande stage IV); and (3) an adult stage in which only the anterior portion of the axial lobe is well defined, and the pseudolobe is poorly defined or defined only along its anterolateral margin (Barrande stage V). Specimens representing Barrande's stage III, with one thoracic segment liberated,

have not been observed in the Eureka district. The information obtained from observation of the developmental stages has been summarized under the discussion of the genus. Detailed descriptions follow.

The immature stage (pl. 20, figs. 4, 7).—The smallest specimen of *P. communis* that has been observed by the writer is 0.5 mm. in length. It has a prominent posteriorly tapered axial lobe that has traces of four shallow transverse furrows outlining four segments and a terminal portion.[1] For purposes of discussion, the segments are numbered consecutively from front to back (pl. 20, fig. 7). This numbering system is used for homologous portions of the axial lobes of the other specimens of the growth series. The furrow outlining the posterior portion of segment II continues across the pleural platform and unites with the marginal furrow. Segment III has a poorly defined posteriorly directed median projection that causes the furrow at the posterior margin of the segment to be bowed backward. There is a suggestion of a similar but much smaller projection at the posterior margin of segment IV. Behind the terminal portion of the axial lobe is a broad, shallow depression that is continuous from the axial lobe to the marginal furrow. Marginal spines are present.

The early mature stage (pl. 20, figs. 5, 8).—Two specimens (0.7 and 0.75 mm. long) representing this stage have been examined. The thoracic segments in the early mature stage are no longer fused to the pygidium so that the length of the pygidium is actually nearly twice that of the pygidial portion of the immature stage.

The axial lobe of the pygidium in the early mature stage is intermediate in form between that of immature and mature individuals. The anterior third is prominent and elevated above the pleural lobes. The posterior portion is subovate in outline, nearly confluent with the pleural platforms, and trilobate. It consists of a median posteriorly tapered area flanked by a pair of areas approximating segments of a circle in outline. The furrows outlining all three of these areas are shallow. A depression extends from the posterior end of the axial lobe to the marginal furrow. Marginal spines are present.

The adult stage (pl. 20, figs. 6, 9, 10).—This stage is represented by many individuals ranging in length from 1 to 4 mm. The outline of the pygidium is the same as that for the early mature stage. The principal differences between the adult and early mature stages are on the pseudolobe. In the mature stage, the pseudolobe is ovate in outline. In larger individuals, only the anterior part is distinctly defined and the trilobation (cf. pl. 20, figs. 9, 10) of the pseudolobe of the younger stage is gone. The shallow depression between the end of the axial lobe and the marginal furrow is also gone. Small individuals in this stage have a minute terminal node on the axial lobe that appears to partially overhang the marginal furrow. The node is an uncommon feature on large specimens.

Plate 20, figures 7–10 show diagrammatically the stages in the development of the pygidium of *P. communis*. The youngest stage corresponds to stage II of Barrande in which the first two segments of the pygidium are incipient thoracic segments. The principal changes in the development of the pygidium between immature and mature stages are the loss of the anterior two segments to the thorax and the appearance of accessory furrows outlining a pseudolobe that includes the true axial lobe. The presence of both dorsal furrows and accessory furrows on the pseudolobe has been noted only on the smallest specimens in the early mature stage. The dorsal furrows disappear in larger individuals and the accessory furrows are gradually reduced until they outline only the anterior portion of the pseudolobe.

Of the five segments of the immature axial lobe, segments I and II, as mentioned above, are subsequently lost to the thorax; segment III is the homologue of the anterior portion of the adult axial lobe. The posteriorly directed projection at the back margin of segment III develops into the axial node. Segments IV and V eventually develop into the posterior portion of the axial lobe. The small posterior projection at the back margin of segment IV cannot be traced with certainty beyond the immature stage. The terminal node may correspond to this projection. If so, nearly the entire pseudolobe develops from segment IV of the immature

[1] The axial lobe of this specimen was partly destroyed while being prepared for photography.

stage. The terminal portion of the immature stage seems to remain small and cannot be recognized with certainty in the adult.

The presence of eight body segments beneath the axial lobe of the pygidium of *P. communis* has been suggested by the writer (Palmer, 1954). Six of these segments are beneath the pseudolobe. Perhaps it is reasonable to assume that as the agnostid grew, new body segments were added at the rear. Thus segment IV in the immature stage may have covered only one or two body segments, and the four additional segments now present beneath the pseudolobe may have been added during development.

Occurrence.—Eureka district. U.S.G.S. (CO) collections, 788, 789, 795, 809, 824, 873, 952, 953. U.S.G.S. (OS) collection 65.

Figured specimens.

	Length (mm.)
pygidium, USNM 24557a	0.5
pygidium, USNM 24557b	0.75
pygidium, USNM 24557c	1.5
pygidium, USNM 24557d	2.5
cephalon, USNM 24557e	3.5
cephalon, USNM 24568	3.5
pygidium, USNM 24568	3.5

Pseudagnostus convergens
Palmer, n. sp.
Plate 19, figures 14, 15

Description.—Cephalon like *P. prolongus* in general proportions and relief. Cheeks with faint reticulate ornament of shallow irregular furrows. Preglabellar median furrow relatively deep directly in front of glabella and near margin, shallow at its midlength.

Pygidium with length and width about equal, sides convergent posteriorly, posterior margin evenly rounded. Marginal spines small, slightly divergent from trend of margin. Anterior portion of axial lobe well defined by deep dorsal furrows. Pseudolobe outlined by shallow accessory furrows. Axial node prominent, extends backward from anterior portion of axial lobe onto pseudolobe.

Discussion.—This species differs from all other described species of *Pseudagnostus* in the outline of the pygidium. It is associated with *Lotagnostus obscurus* Palmer, n. sp. The cephalon differs principally from that of *L. obscurus* by having the axial node on the

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Explanation of Plate 19

Figs. *1, 2*—*Geragnostus brevis* Palmer, n. sp. *1*, cephalon, ×5, USNM 123551, USGS coll. 803 (CO). *2*, holotype pygidium, ×4, USNM 123552, USGS coll. 803 (CO). Pogonip limestone, unit 2. (p. 91)

3, 4—*Geragnostus tumidosus* (Hall and Whitfield), ×4. *3*, holotype cephalon, USNM 24558, from Hamburg Ridge, exact locality not known. *4*, pygidium, USNM 123553, from USGS coll. 872 (CO). Dunderberg shale. (p. 89)

5–7, 10—*Lotagnostus obscurus* Palmer, n. sp., ×3. *5*, cephalon, USNM 123557a, USGS coll. 790 (CO). *6*, holotype pygidium, USNM 123556, USGS coll. 790 (CO). *7*, exfoliated cephalon, USNM 123557b, USGS coll. 790 (CO). *10*, exfoliated pygidium showing faint trilobation of the posterior portion of the axial lobe, USNM 123557c, USGS coll. 790 (CO). Pogonip limestone, unit 1. (p. 92)

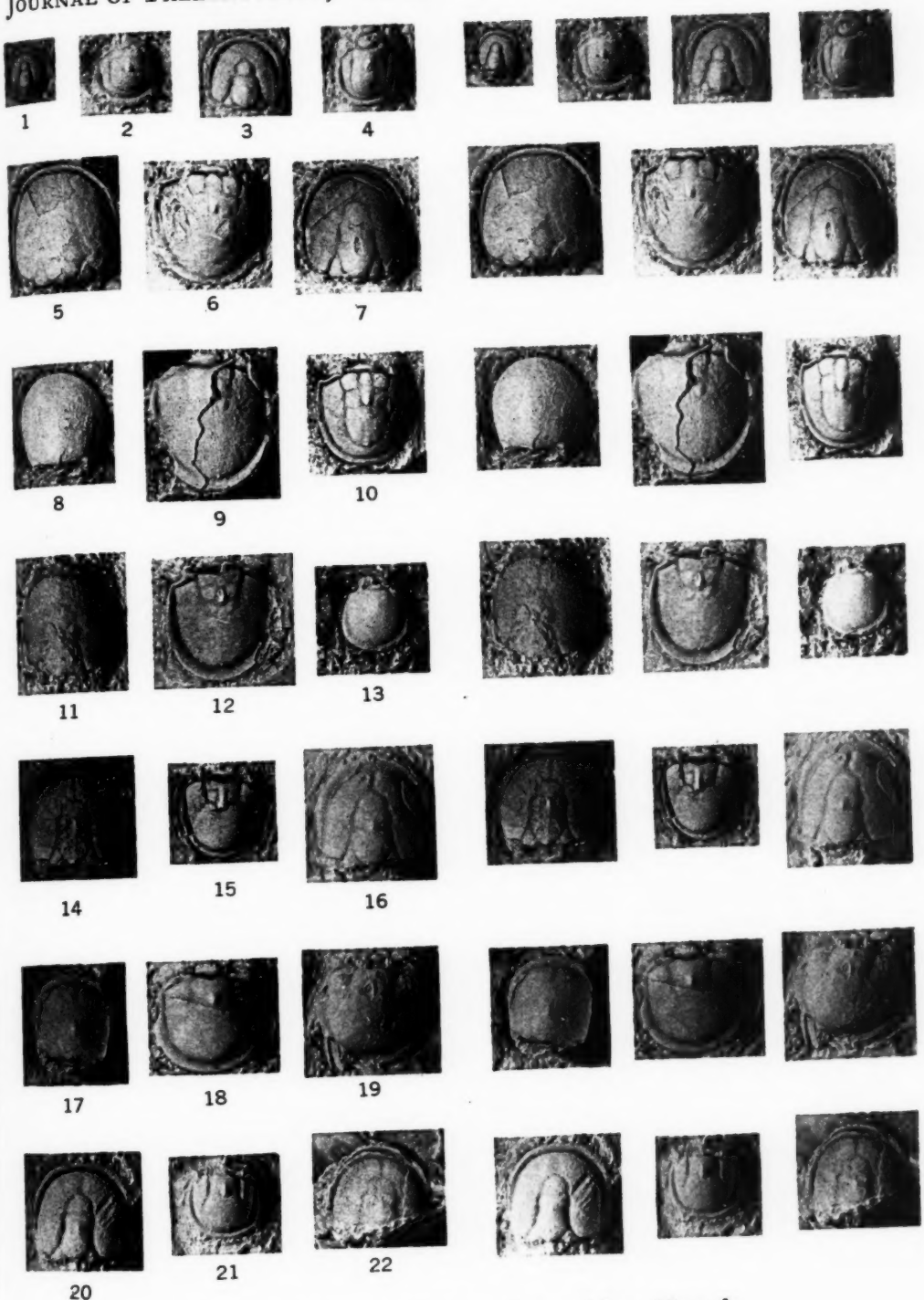
8, 9, 11, 12—*Pseudagnostus laevis* Palmer, n. sp. *8*, cephalon, ×3, USNM 123561, USGS coll. 803 (CO). *9*, partly exfoliated holotype pygidium, ×4, USNM 123559, USGS coll. 1364 (CO). *11*, exfoliated cephalon ×4, USNM 123560, USGS coll. 1365 (CO). *12*, exfoliated pygidium, ×3, USNM 26990, USGS loc. 56 (OS). Pogonip limestone, unit 2. (p. 97)

13—*Litagnostus expansus* Palmer, n. sp. Holotype pygidium, ×4, USNM 123558, USGS coll. 803 (CO): Pogonip limestone, unit 2. (p. 92)

14, 15—*Pseudagnostus convergens* Palmer, n. sp., ×4. *14*, exfoliated cephalon showing muscle scars, USNM 123563, USGS coll. 790 (CO). *15*, holotype pygidium, USNM 123562, USGS coll. 826 (CO). Pogonip limestone, unit 1. (p. 96)

16, 19–21—*Pseudagnostus communis* (Hall and Whitfield), ×4. *16*, exfoliated cotype cephalon of *P. neon* (Hall and Whitfield) here considered conspecific with *P. communis* (Hall and Whitfield) USNM 24568, USGS loc. 65 (OS). *19*, exfoliated cotype pygidium of *P. neon* (Hall and Whitfield), USNM 24568, from USGS loc. 65 (OS). *20*, cephalon, USNM 24557e, and *21*, pygidium, USNM 24557d, Dunderberg shale, exact locality not known. (p. 94)

17, 18, 22—*Pseudagnostus prolongus* (Hall and Whitfield) ×4. *17*, cotype cephalon, USNM 24637. *18*, pygidium, USNM 123564, USGS coll. 825 (CO). *22*, exfoliated cotype cephalon originally illustrated (Hall and Whitfield, 1877, pl. 1, fig. 31) as a pygidium, USNM 24637. Dunderberg shale, (figs. 17, 22) exact locality not known; Pogonip limestone, unit 1 (fig. 18). (p. 98)



Palmer, Upper Cambrian Agnostidae, Nevada

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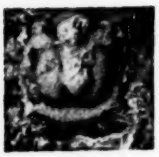

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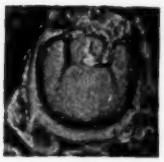

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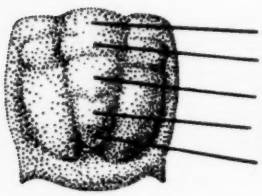

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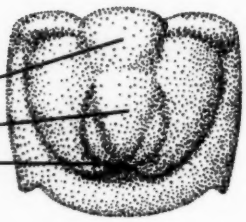

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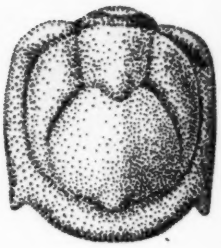

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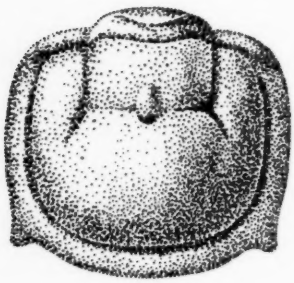

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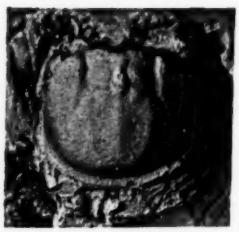

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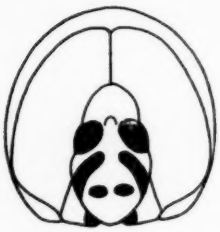

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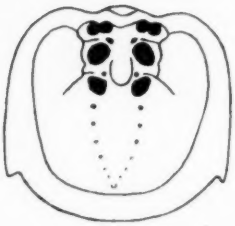

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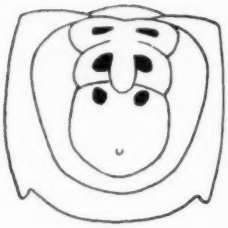

15

Palmer, Upper Cambrian Agnostidae, Nevada

middle glabellar lobe rather than on the posterior lobe.

An exfoliated cephalon of this species (pl. 19, fig. 14; pl. 20, fig. 13) provides information on the disposition of cephalic muscle attachments for *Pseudagnostus*. Four pairs of muscle scars are shown in the illustrations. Each pair has a distinctive shape, size and position in contrast to those scars on the pygidium (pl. 20, figs. 11, 14) which have similar sizes, shapes and positions. The first and third pairs of scars of the cephalon, numbered from the front, are circular or oval in outline. The first pair is the largest, situated adjacent and lateral to the axial node. The third pair is within the posterior part of the posterior glabellar lobe. The second pair is boomerang shaped with one "arm" adjacent to the dorsal furrow and the other extending inward and forward between the first and third scars. The fourth pair of scars is roughly triangular in outline and is located at the inner posterior corners of the basal glabellar lobes. Several other specimens of this species also show these scars and the anterior pair has been observed on cephalons of other species of *Pseudagnostus*.

Westergård (1946, pl. 16, fig. 1) illustrated muscle scars on a cephalon of *Phalacroma glandiforme* (Angelin). The scars on that species and on *Pseudagnostus convergens* appear as roughened areas slightly below the general surface of the exfoliated specimen. In both species, the large anterior pair of scars is adjacent to the axial node. The large irregular posterior scar of *P. glandiforme*, however, is different from the three pairs of scars in the same general area on the cephalon of *P. convergens*.

As in other agnostids, variation in degree of development of the furrows in the axial region is the principal feature contributing to differences in appearance between specimens of this species. Most of these differences are between exfoliated specimens and those still retaining the test.

Occurrence.—Pogonip limestone, unit 1. U.S.G.S. (CO) collections 790, 826, 827.

Figured specimens.—

	Length (mm.)
holotype pygidium, USNM 123562	3
cephalon, USNM 123563	3.5

Pseudagnostus laevis
Palmer, n. sp.
Plate 19, figures 8, 9, 11, 12

Description.—Cephalon somewhat expanded forward, broadly rounded anteriorly, moderately arched transversely, and gently arched longitudinally, width and length about equal. Outer surface nearly smooth, broken only by an axial node and by prominent marginal furrows separating small areas of the posterior margin lateral to the basal glabellar lobes. Exfoliated specimens show a poorly defined trilobed glabella and simple basal lobes, hardly

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Explanation of Plate 20

Figs. *1–3*—*Geragnostus tumidosus* (Hall and Whitfield) *1*, immature pygidium, ×24, USNM 123555c, USGS coll. 955 (CO). *2*, unique pygidium with posteriorly placed axial node, ×8, USNM 123554, USGS coll. 873 (CO). *3*, unique pygidium with anterior pair of furrows outlining lateral lobes on first axial segment, ×8, USNM 123555b, USGS coll. 955 (CO). Dunderberg shale. (p. 89)

4–10—*Pseudagnostus communis* (Hall and Whitfield). Ontogenetic series. Figures *7–10* are drawings of plate 20, figures *4–6* and plate 19, figure *21*, respectively. *4*, pygidium, immature stage, ×30, USNM 24557a; *5*, pygidium early mature stage, ×24, USNM 24557b; *6*, pygidium, mature stage, ×10, USNM 24557c; all from Dunderberg shale, exact locality not known. *7*, drawing of immature stage, ×50. *8*, drawing of early mature stage, ×35. *9*, drawing of small specimen from mature stage with accessory furrow still fairly well developed, ×25. *10*, drawing of larger specimen from mature stage with accessory furrows outlining only the anterior part of the pseudolobe, ×20. (p. 94)

11–15—Specimens showing muscle scars. Figures *13–15* present diagrammatic representations of muscle scars seen on Plate 19, figure *14*, and Plate 20, figures *11, 12*, respectively. *11*, *Pseudagnostus communis* (Hall and Whitfield), pygidium, ×4, UT-32169, from the Riley formation, Lion Mountain sandstone member, central Texas. *12*, *Geragnostus tumidosus* (Hall and Whitfield), pygidium, ×8, USNM 123555a, USGS coll. 955 (CO), Dunderberg shale. *13*, *Pseudagnostus convergens* cephalon, about ×8. *14*, *Pseudagnostus communis* pygidium, about ×6. *15*, *Geragnostus tumidosus* pygidium, about ×15.

elevated above the cheeks; a shallow preglabellar median furrow; and a downsloping border.

Pygidium with general outline subquadrate, evenly rounded posteriorly. Border slightly depressed on axial line. Marginal spines small, situated between one-third and one-fourth of the length of the pygidium from the posterior margin. Pseudolobe not defined. Terminal node present. Anterior portion of the axial lobe tapered backward, divided subequally into two segments by a pair of shallow furrows that extend inward about a third the width of the axial lobe from the dorsal furrow. Axial node prominent, confined to posterior segment. A pair of prominent, closely spaced circular muscle scars is present on the anterior portion of the pseudolobe on exfoliated specimens. Outer surface of pygidium smooth.

Discussion.—*P. laevis* appears to be most similar to *P. clarki* Kobayashi from eastern Alaska, but Kobayashi's specimens are too poorly preserved for adequate comparison. The pygidia of the two species seem to be essentially identical in all observable features. Although Kobayashi (1935a, p. 47) states that the pygidium of his species lacks marginal spines, a reexamination of his figured specimen shows a marginal spine on the right side in approximately the same position as that on the pygidia of *P. laevis*. The exfoliated cephalon described by Kobayashi (1935a, p. 47) lacks a preglabellar median furrow. This characteristic is the main feature separating *P. clarki* from *P. laevis*.

P. laevis differs from all other species of *Pseudagnostus* by having a nearly featureless outer surface of the cephalon, by having only the anterior portion of the axial lobe of the pygidium outlined by furrows, and by having the border of the pygidium slightly depressed on the axial line.

All furrows are better developed on exfoliated specimens. In fact, specimens retaining the test might easily be assigned to one of the genera of smooth agnostids. Only exfoliated specimens show clearly that this species belongs to *Pseudagnostus*.

Special features.—Muscle scars identical to those described for the cephalon of *P. convergens* Palmer, n. sp., in this paper, and to those described for a pygidium of *P. communis* (Hall and Whitfield) in an earlier paper (Palmer, 1954) have been observed on specimens of this species. They are not as clearly shown as on the examples described, but they are faintly visible on the specimens illustrated on plate 19, figures 9 and 11. Drawings showing the dispositon of muscle scars on the cephalon and pygidium of *Pseudagnostus* are shown on plate 20, figures 13, 14.

The muscle-scar patterns seem to be constant for different species of *Pseudagnostus*. More observations of such structures may show them to be valuable features for taxonomic differentiation.

Occurrence.—Pogonip limestone, unit 2. U.S.G.S. (OS) locality 56; U.S.G.S. (CO) collection 803, 815, 1364, 1365.

Figured specimens.—

		Length (mm.)
holotype pygidium,	USNM 123559	5
pygidium,	USNM 26990	6
cephalon,	USNM 123560	4
cephalon,	USNM 123561	4.5

PSEUDAGNOSTUS PROLONGUS
(Hall and Whitfield)
Plate 19, figures 17, 18, 22

Agnostus prolongus HALL and WHITFIELD, 1877, p. 230, pl. 1, figs. 30, 31.

Diagnosis.—Like *P. communis* (Hall and Whitfield) but with glabella, and axial lobe of pygidium poorly defined by shallow dorsal furrows.

Discussion.—The shallow nature of all furrows on the outer surface of the test distinguishes this species from other species of *Pseudagnostus*.

The original figured specimens of this species are both cephalons. The specimen cited as the cephalon by Hall and Whitfield shows the outer surface of the test and the specimen cited as the pygidium by those authors is an exfoliated cephalon that has the posterior margin broken. This led Kobayashi (1939, p. 130) to state that the combination of the two shields into one species was unwarranted. The cephalon was questionably assigned to *Cotalagnostus* by Kobayashi, who had not had the opportunity to examine the type specimens. The presence of a distinct, although poorly-defined, anterior glabellar lobe, and a preglabellar median furrow exclude it from that genus.

Most of the observable variation in appearance of the cephalons and pygidia is caused by exfoliation as in *P. communis*. Exfoliated specimens cannot be differentiated with certainty from specimens of *P. communis*.

Occurrence.—Dunderberg shale, U.S.G.S. (CO) collection 864; Pogonip limestone, U.S.G.S. (CO) collections 825, 956, 957, 958? 959.

Figured specimens.—

	Length (mm.)
cephalon 24637	3
exfoliated cephalon 24637	3.5
pygidium 123564	4

LOCALITY AND FAUNAL LIST

Complete information concerning collecting localities mentioned by number in the text and plate descriptions is given below, together with a list of the agnostid trilobites identified from each. All the collections are from rocks exposed in the area covered by the Eureka mining district special quadrangle sheet.

Numbers listed under (OS) were assigned under a numbering system established by Walcott and Ulrich and used for all Cambrian and Ordovician collections obtained by the U. S. Geological Survey and U. S. National Museum up to about 1940. These numbers are on green stickers attached to the specimens. Numbers listed under (CO) were assigned under a system established by Josiah Bridge since 1940 for Cambrian and Ordovician collections made by members of the U. S. Geological Survey. These numbers are on orange stickers attached to the specimens.

U. S. Geological Survey Collections (OS)

56—Pogonip limestone, unit 2, at Sierra Springs, western base of Lookout Mountain. Collected by C. D. Walcott, 1880.
Geragnostus brevis Palmer, n. sp.
Pseudagnostus laevis Palmer, n. sp.

65—Dunderberg shale—east side of Sierra Canyon opposite Pinnacle peak. Collected by Arnold Hague and J. P. Iddings, 1880.
Pseudagnostus neon (Hall and Whitfield) (=*P. communis* (Hall and Whitfield)

U. S. Geological Survey Collections (CO)

Collections 788 to 882 were made by Josiah Bridge during August and Septemtember, 1939.

788—Dunderberg shale, float, just above Dunderberg-Hamburg contact, 2250 feet S. 13° E. of the Hamburg shaft. Elevation 7950 feet.
Geragnostus tumidosus (Hall & Whitfield)
Pseudagnostus communis (Hall and Whitfield)

789—Dunderberg shale, about 200 feet above the Hamburg limestone, 2050 feet S. 18° E. of the Hamburg shaft. Elevation 8025 feet.
Pseudagnostus communis (Hall and Whitfield)

790—Pogonip limestone, unit 1, 1400 feet S. 28° E. of the Hamburg shaft. Elevation 8115 feet.
Lotagnostus obscurus Palmer, n. sp.
Pseudagnostus convergens Palmer, n. sp.

795—Dunderberg shale, near base, on road to Catlin shaft, about 250 feet from New York Canyon road, 760 feet S. 29° E. of the Catlin shaft. Elevation 7490 feet.
Pseudagnostus communis (Hall and Whitfield)

803—Pogonip limestone, unit 2, saddle between forks of Goodwin Canyon, 2200 feet N. 40° E. of the Eureka tunnel. Elevation 7700 feet.
Geragnostus brevis Palmer, n. sp.
Pseudagnostus laevis Palmer, n. sp.

807—Pogonip limestone, unit 1, southwest slope of Hoosac Mountain, south of the divide at the head of Windfall Canyon, 4360 feet S 8° E. of the Windfall shaft. Elevation 8110 feet.
Lotagnostus obscurus Palmer, n. sp.

809—Dunderberg shale, southwest slope of Hoosac mountain, east of spring in tributary of Secret Canyon, 4780 feet S. 5° E. of the Windfall shaft. Elevation 8075 feet.
Pseudagnostus communis (Hall and Whitfield)

815—Pogonip limestone, unit 2, in saddle 1800 feet S. 12° E. of the New Jackson shaft. Elevation 7355 feet.
Geragnostus brevis Palmer, n. sp.
Pseudagnostus laevis Palmer, n. sp.

824—Dunderberg shale, float, from stone wall just north of the Richmond mine.
Geragnostus tumidosus (Hall & Whitfield)
Pseudagnostus communis (Hall and Whitfield)

825—Pogonip limestone, unit 1, not more than 20 feet above the Dunderberg shale on hill northeast of the Richmond shaft. Just above old railroad grade, 760 feet N. 40° E. of the Richmond shaft. Elevation 6870 feet.
Pseudagnostus prolongus (Hall and Whitfield)

826—Pogonip limestone, unit 1, near top of hill northeast of the Richmond shaft, 980 feet N. 40° E. of the Richmond shaft. Elevation 6905 feet.
Lotagnostus obscurus Palmer, n. sp.
Pseudagnostus convergens Palmer, n. sp

827—Pogonip limestone, unit 1, top of hill northeast of the Richmond shaft, 950 feet N. 47° E. of the Richmond shaft. Elevation 6920 feet.
Lotagnostus obscurus Palmer, n. sp.

864—Dunderberg shale, north side of Widewest Canyon, 900 feet N. 55° E. of the Cyanide shaft. Elevation 6470 feet.
Geragnostus tumidosus (Hall & Whitfield)

872—Dunderberg shale, float, dump of prospect, 1350 feet N. 64° W. of U.S.N.M. 10, near Bullwhacker mine. Elevation 6327 feet.
Geragnostus tumidosus (Hall & Whitfield)

873—Dunderberg shale, float, dump of prospect, 1300 feet S. 74° W. of U.S.N.M. No. 10, near Bullwhacker mine. Elevation 6365 feet.
Geragnostus tumidosus (Hall & Whitfield)
Pseudagnostus communis
(Hall and Whitfield)

882—Pogonip limestone, unit 1, on south slope of hill southeast of the Hamburg mine in Windfall Canyon, 850 feet N. 28° E. of the New Windfall shaft. Elevation 7590 feet.
Lotagnostus obscurus? Palmer, n. sp.

952–959—These collections are from an unfaulted section of the Dunderberg shale and the lower part of the Pogonip limestone that extends eastward from the prospect pits 500 feet north of the Windfall shaft in the south central rectangle of the Eureka mining district quadrangle. Collected by A. R. Palmer, August 1951 and 1953.

952—Dunderberg shale, about 67 feet above the base.
Geragnostus tumidosus (Hall & Whitfield)
Pseudagnostus communis
(Hall and Whitefield)

953—Dunderberg shale, about 121 feet above the base.
Geragnostus tumidosus (Hall & Whitfield)
Pseudagnostus communis
(Hall and Whitfield)

954—Dunderberg shale, about 144 feet above the base.
Geragnostus tumidosus (Hall & Whitfield)

955—Dunderberg shale, about 215 feet above the base.
Geragnostus tumidosus (Hall & Whitfield)

956—Pogonip limestone, unit 1, 15 feet below top of lowest massive limestone.
Geragnostus tumidosus (Hall & Whitfield)
Pseudagnostus prolongus
(Hall and Whitfield)

957—Pogonip limestone, unit 1, 13 feet below top of lowest massive limestone.
Pseudagnostus prolongus
(Hall and Whitfield)

958—Pogonip limestone, unit 1, 10 feet below top of lowest massive limestone.
Pseudagnostus prolongus?
(Hall and Whitfield)

959—Pogonip limestone, unit 1, lower part of lowest massive limestone.
Pseudagnostus prolongus
(Hall and Whitfield)

1364—Pogonip limestone, unit 2, 50 feet below top of unit.
Geragnostus brevis Palmer, n. sp.
Pseudagnostus laevis Palmer, n. sp.

1365—Pogonip limestone, unit 2, 70 feet below top of unit.
Pseudagnostus laevis Palmer, n. sp.

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POSSIBLE NAUTILOID MANDIBLES FROM THE PERMIAN OF ARIZONA

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Museum of Northern Arizona, Flagstaff, Arizona

ABSTRACT—Specimens from the Kaibab limestone (Middle Permian) of northern Arizona are described and tentatively referred to d'Orbigny's genus *Rhynchoteuthis*, as mandibles of nautiloids, with the specific name of *Rhynchoteuthis kaibabensis*.

AMONG fossil material collected in the Alpha member of the Kaibab limestone (McKee, 1938) in the neighborhood of Flagstaff, Arizona, several small specimens occur which is some ways resemble the nautiloid mandibles that are fairly common in the Mesozoic of England and western Europe, especially in the Lias and Chalk. As far as the writer has been able to learn, no such mandibles have been previously reported from the Permian and older formations, and it seems worthwhile to put on record the occurrence of these specimens as possibly the mandibles of paleozoic nautiloids.

David Nicol (1944, p. 553) describes the strata from which the material here described was collected as "thin bedded dolomites, dolomitic sandstone. . . " and believes that they represent deposits in shallow, land-locked and somewhat hypersaline seas, and that the nautiloids were swept into these sediments by waves or currents. He recognized, however, the possibility that they may be true facies fossils, species which had adapted themselves to conditions somewhat abnormal for such cephalopods.

It is significant that all of the specimens in question were collected in the particular horizon near the top of the formation from which almost all the nautiloids of the Kaibab have come.

The fossils in this horizon occur as external and internal molds so that the original shell material cannot usually be determined. The fauna consists mainly of shallow-water species of brachiopods and molluscs and has been described in a recent paper by Halka Chronic (1952).

Almost all the nautiloid mandibles of the Mesozoic occur as the "beaks" only, and were described originally by d'Orbigny (1846) and by Pictet and de Loriol (1858) under the name *Rhynchoteuthis*. Among the illustrations and descriptions of forms from the Neocomian of Voirons in southwestern France by Pictet and de Loriol are those of one specimen with wing-like expansions, which are very similar to those on the Kaibab forms. The French specimen, described under the name *Rhynchoteuthis sabaudianus*, appears as the outer face of the mandible exposed on the matrix, whereas the Kaibab specimens seem to be molds and impressions of the interior surface only, except one individual which includes complete molds of the two lateral "wings."

A detailed comparison of the Kaibab specimens with the illustration and description of Pictet's species is somewhat difficult because they represent opposite faces of the mandible. Furthermore the Pictet specimen shows only the beak, one complete "wing" and warped fragments of another. Pictet and de Loriol (1858, pp. 37–38), in their descriptions of this unique specimen, interpret these wings as follows (translation by the writer):

> The solid parts of the beak are the only ones comparable to what is known of *Rhynchoteuthis;* they are accompanied by widely extended, wing-like expansions which seem to have been thin and delicate, membranous, in fact. The one specimen which has revealed their existence shows that they were three in number, although only two are preserved, the third being indicated only by considerations of symmetry. The first is a continuation of the posterior triangular face of the beak . . . the other two are lateral, and, as we have said, we have only one of these preserved and merely assume the existence of the other. It resembles a large membranous scale.

Of the first (median) wing-like expansion there is no trace in the Kaibab material,

and it may be that the fragmentary traces of a wing on the right side of Pictet's specimen represent distorted remnants of the right wing, which would correspond with the well-preserved one on the left side, and that the median wing did not exist. Furthermore, the "wings" in the Kaibab material, as shown by a latex cast of specimen G2-1672, are not by any means thin and membranous, being from 1–2 mm. thick, each inner face bearing a raised elliptical area which may be a muscle attachment, and the outer faces being somewhat scaly as though the material were chitinous. The proportions of the beaks exposed beyond the chitinous extensions are also noticeably different in the two cases, although it may be that the chitinous material covered the beak more completely on the inner side than on the outer.

The general shape of the Kaibab specimens can be seen more readily from the photographs than from a description. It might be called "saddle-shaped," with a rounded point, the beak, in front, the wings forming the skirts of the saddle and sloping from the median ridge at angles of 90–100 degrees.

The common mandibles from the Lias have been referred to as *Temnocheilus* by Schlotheim, having been found associated with shells of this genus. L. F. Spath, however, informed the writer (personal communication, 1952) that, as the genus *Temnocheilus* is now restricted to the Paleozoic, the Mesozoic material should properly be referred to Mojsisovic's genus *Germanonautilus*. However, no nautiloid from the Kaibab has been referred with certainty to the genus *Temnocheilus* by Miller and Youngquist (1949); the coiled forms that have been identified so far are referred to the genera *Aulametacoceras*, *Domatoceras*, *Stearoceras* and *Tainoceras*, all of which, however, are fairly close to *Temnocheilus*.

Until or unless better-preserved specimens like those mentioned are found, preferably in direct association with the conch of a nautiloid, it may be well to consider them only as possible nautiloid mandibles and to refer them for the time being to d'Orbigny's genus *Rhynchoteuthis*. Accordingly, they are here tentatively described, and are listed in the collections of the Museum of Northern Arizona under the name *Rhynchoteuthis kaibabensis*, n. sp.

ACKNOWLEDGMENTS

The writer wishes to express his sincere thanks to the American Museum of Natural History for the loan of the original publications on the subject by A. d'Orbigny and by Pictet and de Loriol; also to Dr. L. F. Spath for suggestions and for the opportunity to see the South Kensington collections of fossil nautiloid mandibles; to Dr. A. K. Miller for his studies of the Kaibab Nautiloids in the collections of the Museum; and

TABLE 1.—COMPARISON OF *Rhynchoteuthis sabaudianus* (PICTET & DELORIOL) AND *R. kaibabensis* BRADY, N. SP.

	Length of complete beak	Exposed portion of beak	Length of wing	Width of wing	Angle formed by side of beak	Angle between wings	Total length	Total width
R. sabaudianus Pictet & deLoriol	13*	9	28	18	65°	?	30	?36
R. kaibabensis G2-351 Holotype	?	2	14	8.5	72°	92°	15	12
R. kaibabensis G2-6626	?	2	11	6	62°	122°	12	11
R. kaibabensis G2 .1352	?	1.4	6	4	70°	90°	8	7.4
R. kaibabensis G2 .1672 Latex cast. Paratype	?	?2	11	8	60°	100°	13	12

* Linear measurements in mm.

to E. T. Nichols for valuable assistance in photographing the Kaibab material.

SYSTEMATIC DESCRIPTION

Genus RHYNCHOTEUTHIS d'Orbigny, 1846

RHYNCHOTEUTHIS KAIBABENSIS Brady, n. sp.

Plate 21, figures 2–8

The specimens described here are referred tentatively to d'Orbigny's genus on the basis of their resemblance to *R. sabaudianus* Pictet and de Loriol, as stated above.

Description.—Impressions of roughly triangular shape, saddle-like in form, showing a sharp, presumably calcareous beak, with two rounded wing-like, probably chitinous, lateral extensions, sloping downwards and forming an angle of 90° to 100° with each other, each bearing a raised oval area on the inner side, probably for muscle attachment. The dimensions of specimens found so far vary from 15×13 mm. to 8×7 mm., the length being always slightly more than the width. The midline in profile is deeply concave between the lateral extensions, the forward portion of the profile being slightly convex. The impression of the beak extends only about one-sixth of the length of the whole mandible, and shows that the under side was slightly concave, unlike that of the Mesozoic species.

Holotype.—G2-351, natural impression of the inner side of the mandible; length 15 mm., width 12.5 mm.

Paratype.—G2-1672, natural mold of the mandible showing details of both faces on the "wings"; length 13 mm., width 12 mm.

Occurrence.—Alpha member of the Kaibab limestone (Middle Permian) near Bottomless Pits, 5 miles east of Flagstaff, Arizona.

MANUSCRIPT RECEIVED OCTOBER 23, 1953

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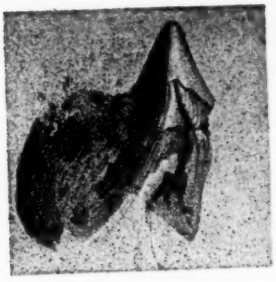
EXPLANATION OF PLATE 21

FIG. *1—Rhyncholeuthis sabaudianus*, ×1; from Pictet and de Poriol (1858). (p. 103)

2–8—Rhyncholeuthis kaibabensis Brady, n. sp. *2–4*, Paratype, G2-1672, ×3.5. *2*, Latex cast of inner surface of mandible. *3*, Posterior view, showing thickness of lateral extensions and raised muscle attachments. *4*, Under side of right extension, showing scaly, chitinous appearance. *5*, *6*, Holotype, G2-351, surface and lateral views, ×2. *7*, *8*, G2-6626, surface and lateral views, ×2. (p. 104)



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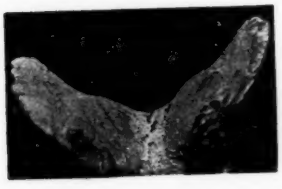

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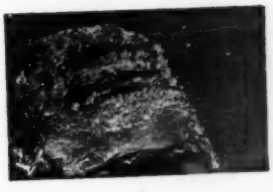

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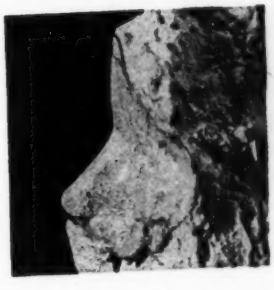

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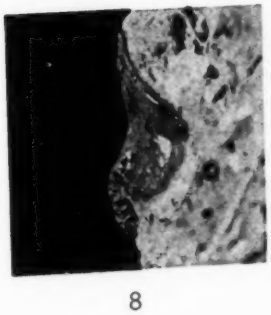

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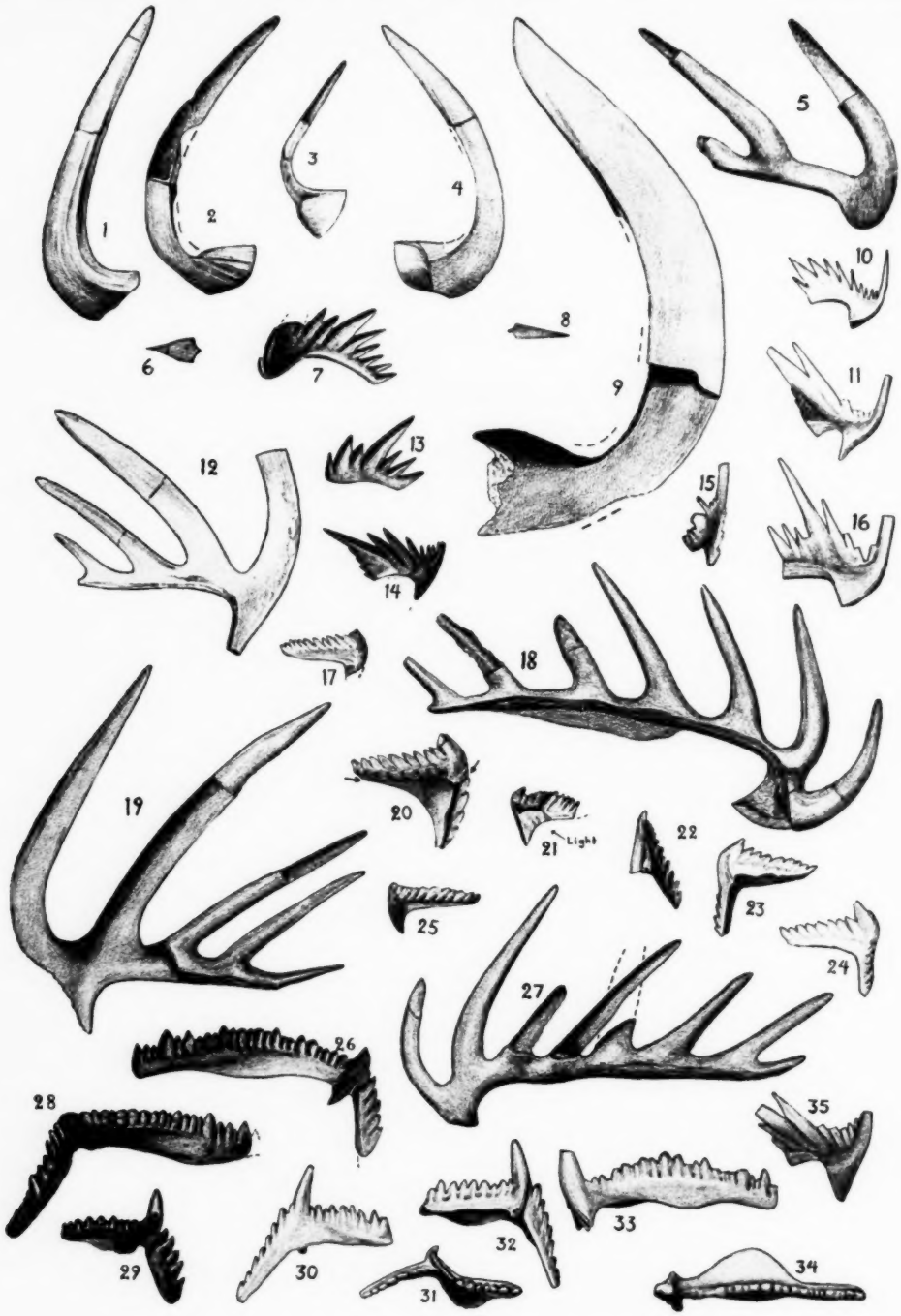
Brady, Permian nautiloid mandibles, Arizona



Lindström, Hadding's 1913 conodonts

JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 1, PP. 105–111, PL. 22, 1 TEXT-FIG., JANUARY 1955

THE CONODONTS DESCRIBED BY A. R. HADDING, 1913

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ABSTRACT—The Swedish Ordovician conodont species erected by Hadding in 1913 are elucidated by new material. The types and typoids are embedded in shale and have been partly laid bare. Hadding's valid genus *Periodon* has been entirely neglected by subsequent workers.

A. R. HADDING, in 1913, was the first to discern different conodont species in the Ordovician of Sweden. He erected ten species and one genus.

Hadding's specimens were found in shale and studied on the bedding planes, as were most conodonts described before 1933. Further, his optical equipment seems to have been unsatisfactory compared with present standards. For these reasons one might suspect a revision of his material to be needed.

The specimens are from the lower *Dicellograptus* shale of Scania, the southernmost province of Sweden. The shale member in question may roughly correspond to the upper part of the Chazyan of North America. All the specimens figured by Hadding are from the zone of *Climacograptus haddingi* Glimberg (= *Climacograptus putillus* of Hadding's work) of Fågelsång, near Lund, and all of them but one, according to the labels attached to them, were found in the upper part of the section E15. One specimen, the one named *Drepanodus robustus* (not, as indicated by the explanation to Hadding's plate 1, the one named *Drepanodus falcatus*) is from E14a. In this connection it may be mentioned that the locality indication given by Fay (1952, p. 90) is incomplete and somewhat misleading. He gives the locality as E15, S. Sweden. The Fågelsång area, along with several other areas in southernmost Sweden with well-exposed Cambro-Silurian strata, was worked through by Moberg and his disciples

EXPLANATION OF PLATE 22

Magnification ×30, unless otherwise indicated

FIGS. *1, 2, 4, 6—Acontiodus robustus* (Hadding). *1*, ×19, LO 2344 T, holotype, lowermost part of Fågelsång E14a. *2, 4*, Fågelsång E15, upper part. *6*, cross section. (p. 108)

3—Acontiodus? sp. LO 2343 T, Fågelsång E15, upper part. (p. 108)

8, 9—Acontiodus falcatus (Hadding). *8*, cross section. *9*, ×19, LO 2342 T, holotype, Fågelsång E15, upper part. (p. 106)

5, 18, 27—Cordylodus spinatus (Hadding). *18*, LO 2347 t, holotype, Fågelsång E15, upper part. *5, 27*, Fågelsång E15, upper part. (p. 109)

7, 13—Chirognathus alternans (Hadding). *7*, LO 2346 T, holotype, Fågelsång E15, upper part. *13*, same horizon and locality. (p. 108)

10, 11, 14–16, 35—Periodon aculeatus Hadding. *10, 35, Schroeteri* limestone of Öland, Gärdslösa, 400 m. east of main road. *11, 15, 16*, same formation, Gärdslösa, 1000 m. east of main road. *11*, lateral (inner) and *15*, posterior view of specimen. *14*, LO 2353 T, holotype, Fågelsång E15, upper part. (p. 110)

12, 19—Cordylodus ramosus Hadding. Fågelsång E15, upper part. *19*, LO 2345 T, holotype. (p. 108)

17, 20–25—Periodon serra (Hadding). *17, 20*, Fågelsång E15, upper part, arrows to *20* indicating upper limit of part preserved as impression and mould. *21*, LO 2352 t, typoid, Fågelsång E15, upper part. *22–24*, specimen from the *Schroeteri* limestone of Öland, the ditch south of N. Kvinneby, posterior and lateral views. *25*, Fågelsång E14a, lowermost part. (p. 110)

26, 28–34—Prioniodus alatus Hadding. *26*, impression of holotype. *28*, LO 2348 T, holotype, Fågelsång E15, upper part. *29*, LO 2349 t, typoid, Fågelsång E15, upper part. *30–32*, specimen from the *Schroeteri* limestone of Oland, the shore at Gärdslösa bodar, in superior and lateral views. *33, 34*, specimen from the *Schroeteri* limestone of Öland, Folkeslunda, the fire well east of the main road, lateral and superior view. (p. 111)

at the close of the last and the beginning of the present century, and they used separate systems of indices for the sections of each area. E15 in this connection refers to the classical Fågelsång area and the index will have no meaning without that information. Some data about Hadding's figured specimens are summarized in table 1. In addition to these specimens, Hadding collected a large number of others, some of which belong to the species figured. At least eight other species are represented, some of which are highly characteristic. From this collection, a fairly good idea about the species can be gained. In order to get richer material I searched at E15 for the band of shale in which Hadding found most of his conodonts. Because of the weathered nature of the outcrop, that was in vain until, by chance, and after this manuscript was prepared and sent for publication, I secured specimens from the stratum and locality given by Hadding, with numerous conodonts. These do not in any way deviate from the descriptions given below.

Conodont faunas from the grey *Schroeteri* limestone of the Isle of Öland proved to contain at least one highly characteristic conodont found, but not described, by Hadding, as well as three of the conodont species erected by him, viz. *Peridon aculeatus*, *Periodon serra* and *Prioniodus alatus*. The localities at which this fauna occurs are to be found on the topographical 1:100,000 mapsheet 17, Kalmar. They are, in the parish of Gärdslösa, about 400 m. east of the main road, at the small byroad to Gärdslösa bodar, and about 1000 m. east of the main road at the same bypath; in the parish of Sandby, where a path that departs at a right angle from the main road 1 km. south of S. Sandby ends at the shore; and in the parish of Stenåsa, just east of the main road, in the ditch south of N. Kvinneby, 1 m. above the water surface. *Prioniodus alatus* was also found in higher and lower levels of the *Schroeteri* limestone, as well as in the underlying red *Platyurus* limestone.

I am aware that the specimens from the *Schroeteri* limestone do not contribute objectively to fix the meaning of Hadding's species. However, to me there is no doubt that they belong to the species erected by Hadding.

The terminology used in this paper mainly differs in two respects from the current terminology, as represented in Fay, 1952, for example. In compound conodonts, I do not differentiate the processes of the base into anticusp, bar, etc., but refer to them all as anterior, lateral or posterior process according to their position. They may carry denticles or be smooth. Further, I refer to the basal stretch of the posterior edge as oral edge, even in simple conodonts. It is oriented horizontally, and in relation to it, the cusp (and in compound conodonts the denticles) are proclined, erect, recurved or reclined, as shown by text-figure 1. This relation has proved to be of some importance in the Swedish conodont faunas that I have examined.

The specimens are kept at the Institute of Paleontology of the Lund University.

ACONTIODUS FALCATUS (Hadding)
Plate 22, figures 8, 9

Drepanodus falcatus HADDING, 1913, p. 30, pl. 1, fig. 3.

Holotype.—LO 2342 T, Hadding 1913, pl. 1, fig. 3; this paper pl. 22 fig. 9.

Diagnosis.—A recurved *Acontiodus* with anteroposteriorly wide, laterally flattened cusp. No other costae than the two required in the genus.

Description.—The exact shape of the basal cavity is unknown. It opens backward only. The oral edge probably is not very sharp. In lateral view, it may be somewhat

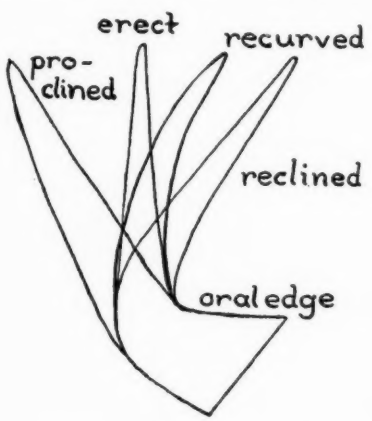

FIG. 1—Illustrating the terms reclined, recurved, erect and proclined.

TABLE 1.—THE SPECIMENS FIGURED BY HADDING

Hadding's figures	Number in collection	Name given by Hadding	Figure in this paper	Valid name	Condition of specimen
Pl. 1, fig. 3	LO 2342 T	*Drepanodus falcatus*	Pl. 22, fig. 9	*Acontiodus falcatus*	Basal part preserved as impression.
fig. 4	LO 2343 T	*Drepanodus verutus*	fig. 3	*Acontiodus*? sp.	Undeterminable
fig. 5	LO 2344 T	*Drepanodus robustus*	fig. 1	*Acontiodus robustus*	Entire. Basal stretch of posterior edge exposed by me.
fig. 6	LO 2345 T	*Cordylodus ramosus*	fig. 19	*Cordylodus ramosus*	Mostly preserved as impression.
fig. 7	LO 2346 T	*Polygnathus alternans*	fig. 7	*Chirognathus alternans*	Impression. Left extremity laid bare by me.
fig. 8	LO 2347 t	*Polygnathus spinatus*	fig. 18	*Cordylodus spinatus*	Entire. Cusp and anterior denticles partly laid bare by me.
fig. 9	LO 2348 T	*Prioniodus alatus*	fig. 28	*Prionodus alatus*	Cusp and anterior process missing. End of lateral process exposed by me.
fig. 10	LO 2349 t	*Prioniodus alatus*	fig. 29	*Prioniodus alatus*	Anterior process missing. Cusp broken away while prepared, but restored in previous position by glue.
fig. 11	Missing	*Prioniodus discedens*			
fig. 12	Missing	*Arabellites serra*			
fig. 13	LO 2352 t	*Arabellites serra*	fig. 21	*Periodon serra*	Anterior part except process preserved as impression. 2 of posterior denticles laid bare by me. Specimen partly treated with HCl to reveal shape of basal cavity.
fig. 14	LO 2353 T	*Periodon aculeatus*	fig. 14	*Periodon aculeatus*	All except anterior part preserved as impression.

convex rather than straight. The anterobasal angle is almost as far back as the posterior end of the oral edge. The cusp is recurved and rather long. It is wide anteroposteriorly, very thin transversely, and sharpedged. The posterolateral costae are distinct but not very prominent. There are no costae except these. The lateral faces are quite flat.

Remarks.—There is only one specimen, the holotype, showing all these characteristics. In one specimen, the outline of the base recalls this species, but in other respects that specimen is an *A. robustus*. Another specimen has the wide, thin cusp of this species but is furnished with several aditional costae and the base of *A. robustus*. Thus, one cannot say for sure that *Acontiodus falcatus* is a very good species or that the above characterization is exhaustive.

ACONTIODUS ROBUSTUS (Hadding)
Plate 22, figures 1, 2, 4, 6

Drepanodus robustus HADDING, 1913, p. 31, pl. 1, fig. 5.

Holotype.—LO 2344 T, Hadding 1913, pl. 1, fig. 5b; this paper pl. 22, fig. 1.

Diagnosis.—A long, rather slender, slightly recurved *Acontiodus*, sharply keeled anteriorly and with a marked tendency to develop additional costae. Basal cavity roughly conical.

Description.—The cross section of this species is that of an *Acontiodus*, with one strong costa to each side of the about equally well developed posterior keel. The presence of additional smaller costae in the bigger specimens might warrant its reference to the form genus *Scolopodus*. However, a certain subjectivity seems unavoidable in referring conodonts to form genera. In this case, the chief feature of the cross section, as well as the absence of additional costae in some specimens, had led me to refer the species to *Acontiodus*.

The cusp is long and slender, more or less recurved. The oral edge is thin, sharp and straight. In side view, the aboral margin is convex to a varying extent. The anterobasal angle may be rounded and is situated far backward, almost straight beneath the anterior end of the oral edge. The anterior edge is thin and sharp, making a long, rather smooth curve.

Remarks.—The species is highly similar to *A. arcuatus* Lindström, 1954, of the Arenigian of Sweden. From that species it differs in being always less thin at the anterobasal angle. In *A. robustus*, the anterobasal angle is more rounded than is usually the case in *A. arcuatus*. In *A. arcuatus*, the anterior edge is not so thin and sharp.

Material.—Eleven specimens.

ACONTIODUS? sp.
Plate 22, figure 3

Drepanodus verutus HADDING, 1913, p. 31, pl. 1, fig. 4.

This conodont specimen (LO 2343 T) is too small and too fragmentary to be determined with certainty, even to the genus. There is, perhaps, a faint trace of a posterolateral costa, so I believe it could be an *Acontiodus*, maybe a young specimen of *A. robustus*.

CHIROGNATHUS ALTERNANS (Hadding)
Plate 22, figures 7, 13

Polygnathus alternans HADDING, 1913, p. 32, pl. 1, fig. 7.

Holotype.—LO 2346 T, Hadding 1913, pl. 1, fig. 7; this paper, pl. 22, fig. 7.

Diagnosis.—A *Chirognathus* with rather long, slightly arched base and several denticles of different sizes, none of which is longer than the base. All the denticles straight or nearly so, little diverging, leaning strongly in one direction.

Description.—Only one side, the outer, is known. It is very smoothly convex. the denticles are little curved, sharpedged and nearly straightedged. At least one of the denticles is almost as long as the base. Basally, the denticles are closely crowded. They diverge but little, all leaning rather strongly in one direction. The aboral margin forms a more or less smooth arch. The lateral curvature is slight.

Remarks.—The variability within the *Chirognathus* species being rather great, I hesitate little in figuring the specimen of plate 22, figure 13 as another instance of this species.

Material.—Two specimens, both impressions.

CORDYLODUS RAMOSUS Hadding
Plate 22, figures 12, 19

Cordylodus ramosus HADDING, 1913, p. 31, pl. 1, fig. 6.

Holotype.—LO 2345 T, Hadding 1913, pl. 1, fig. 6; this paper, pl. 22. fig. 19.

Diagnosis.—A *Cordylodus* with long, slender, discrete, reclined denticles numbering three to four, the one behind the cusp as big as the latter, the next two to three considerably smaller. Anterobasal angle sharp, directed obliquely backwards.

Description.—The basal cavity proper is sharply conical, with its apex far forward. It does not extend behind the cusp, but along the aboral edge of the unit there runs a thin, longitudinally striated zone that is formed by the edges of the growth lamellae. Instead of overlapping, as in an ordinary basal sheath, each lamella here leaves a thin strip of the next older lamella uncovered. I have elsewhere referred to such a zone as an "inverted basal cavity."

The cusp and the denticles are lanceolate

in cross section, often with faint anterior and posterior keels. The cusp is directed forward basally, but becomes somewhat recurved upward. It is about as long as the posterior process. The denticles are slender, almost straight and reclined, the one at the posterior extremity very strongly so. The front denticle is as big as the cusp, the others considerably smaller. A line through the tips of the denticles will be almost straight, running at approximately right angles to the aboral margin of the process.

Material.—Seven specimens.

Cordylodus spinatus (Hadding)
Plate 22, figures 5, 18, 27

Polygnathus spinatus Hadding, 1913, p. 32, pl. 1, fig. 8;

Holotype.—LO 2347 t, Hadding 1913, pl. 1, fig. 8, this paper, pl. 22, fig. 18.

Diagnosis.—A rather irregular *Cordylodus* with the base strongly arched anteriorly, then almost straight. Cusp and denticles rather long and slender, discrete, lanceolate in cross section. Denticles reclined, as many as seven in number.

Description.—As in *C. ramosus*, the basal cavity proper is restricted to the foremost portion and is inverted posteriorly. The edges of the cusp and denticles are sharp. I could not find any specimen with obviously keeled edges. The cusp basally is directed forward, curving smoothly to become suberect apically. It is much shorter than the posterior process. The denticles are widely spaced. They are rather long and slender. The foremost three to four denticles are as big as, or bigger than the cusp. The denticle just behind the cusp is recurved. The rest of the denticles as a rule are reclined and in one plane, the specimen of plate 22, figure 27 being a noteworthy exception. Because of the anterior arching of the aboral margin, the anterobasal angle is pushed backward. In the holotype, there is a carbonaceous lamina along the posterior part of the aboral margin. Such laminae are rather commonly found attached to the conodonts of Fågelsång E15.

Material.—Eight specimens.

Genus Periodon Hadding

Type species.—*Periodon aculeatus* Hadding, 1913 (monotypy).

Remarks.—There is no description, nor a diagnosis, nor a definition of this genus. It is valid by the existence of a type species that is described and figured (Hadding 1913, p. 33).

The type species possesses certain striking characteristics, such as the strong reclination and blade-like appearance of the denticles and the very large size of one of the posterior denticles that contrasts with the foremost denticles, which are small. I believe that, had the genus *Periodon* not been erected for this species, some authors might have referred it to *Phragmodus* Branson & Mehl, 1933.

That the relative size of the denticles, though rather constant, may vary within the same species appears from plate 22, figure 10. In this specimen from the *Schroeteri* limestone, the big denticle is not very different from the ones immediately in front of it. I am convinced that the relative size of the denticles and other similar characters such as proportions, amount of curvature, deflections, etc. do not provide a stable basis of conodont classification. The most stable classification possible, of compound, nonplatform conodonts will, I believe, arise if attention is paid to such characters as the number and position of the processes (or edges) and which of these are denticulate.

Thus, the characters of the type species that are, in my opinion, the most important are that there are denticles along the oral (posterior) and the anterior edge and that there is a third, lateral process that does not carry denticles. The lateral process of the type species as a rule is little protruding, being confined to a costa that runs down the cusp to the aboral margin.

Probably, again, all will not agree with me in regarding a costa as equivalent to a process. However, I have noticed several times that, in compound conodonts, a costa that as a rule does not carry denticles may occasionally do so. To most costae that reach the aboral margin there is in compound conodonts a more or less pronounced bulge of the latter, i.e., a small process. It appears that there is no absolute difference between a costa and a process. The line of separation should be drawn between the presence and the absence of any such feature.

The admittedly rather great disadvan-

tage of this basis of classification is that it is not quite natural. Even though in time it might be developed in a more natural direction, one must not forget that it is only with form genera that one is dealing.

Diagnosis.—Compound conodonts with anterior and posterior denticulate edges or processes and a lateral costa or process that is not denticulate.

PERIODON ACULEATUS Hadding
Plate 22, figures, 10, 11, 14–16, and 35

Periodon aculeatus HADDING, 1913, p. 33, pl. 1, fig. 14.

Holotype.—LO 2353 T, Hadding 1913, pl. 1, fig. 14; this paper, pl. 22, fig. 14.

Diagnosis.—A *Periodon* with no free anterior or lateral process, the anterior edge turned obliquely sideward, minutidenticulate, the posterior process with blade-like denticles, at least one of which equals the cusp in size.

Description.—The basal cavity is rather deep anteriorly. Posteriorly, there is a rather wide zone of "inverted basal cavity" (cf. *Cordylodus ramosus*). The aboral margin is strongly arched anteriorly.

The posterior process is rather long. It carries several sharpedged, pointed denticles that are thin and rather broad. They are fused basally. They are straight and reclined, very strongly so at the posterior end. The denticles immediately behind the cusp are very small, crowded against the latter. Next come a few rather big, reclined denticles, then a very big denticle that may be as long as or longer than the cusp. The denticles posterior to the big denticle are small and, as a rule, there are few of them. The posterior part of the posterior process is more or less bent outward, as may appear from plate 22, figure 15.

The anterior edge is slightly deflexed to the inner side. It carries a few small denticles that lean closely against the edge, so that they can hardly be said to stand free. Toward the anterobasal angle the edge leans backward.

On the outer side, there is a sharp ridge that runs down the cusp to the aboral margin. It should be remarked that this ridge, while found in the majority of the specimens, is not distinct in all the specimens that must be referred to this species.

The cusp is suberect, rather slender and not flattened.

Material.—From Fågelsång E15, one specimen, the holotype. From the *Schroeteri* limestone of Öland, 30 specimens.

PERIODON SERRA (Hadding)
Plate 22, figures 17, and 20–25

Arabellites serra HADDING, 1913, p. 33, pl. 1, figs. 12, 13.

Holotype.—Hadding's pl. 1, fig. 12. According to the card index of the type collection of the Paleontological Institute of Lund, the specimen is missing. It has no number in the collection. In spite of renewed search in the type collection, as well as among the other specimens collected by Hadding, this specimen failed to turn up. The typoid, LO 2352 t, Hadding's pl. 1, fig. 13, this paper pl. 22, fig. 21, is somewhat fragmentary, yet perfectly determinable.

Diagnosis.—A *Periodon* with the anterior and posterior processes carrying a number of small, subequal-sized denticles. Anterior process turned sideward. Cusp small, reclined along with the oral denticles.

Description.—The basal cavity is deep, extending all along the processes, the sheath wide and smooth. The aboral margin is broadly arched.

The posterior process is straight or nearly so. It carries a row of denticles that decrease evenly in size toward the posterior end. They are rather, blunt, fused basally, and reclined. The anterior denticulate edge is about as long as the oral edge. It makes an approximately right angle with the latter. It is slightly deflected toward the inner side and carries a row of suberect, basally fused denticles that are almost as big as those of the posterior process. On the outer side of the unit, there is an undenticulate costa that runs from the cusp to the aboral margin along an outward bulge of the sheath.

The cusp is small and rather stout. It is reclined.

Remarks.—In the shale material, it is the rule that only the posterior process is directly observable, and it was the only process known to Hadding. In a couple of specimens the anterior denticulate edge was to be found, and in a few others, the outer side of which was laid bare, I found the undenticulate lateral process. By etching the specimens away and breaking away the

mould of the basal cavity I found the impressions of all of the processes. The typoid merely shows part of the posterior process, the mould of the basal cavity and the impresssion of the cusp. The anterior process has been broken away and the lateral process should be hidden behind the mould of the cavity.

Material.—From Fågelsång E15, nine specimens. From the *Schroeteri* limestone of Öland, 20 specimens.

Genus Prioniodus Pander

As shown by Öpik (1936, pp. 106–107) the type species, *P. elegans* Pander, 1856, is provided with three denticulate processes. Öpik's figure seems to show one of these to be anterior, one lateral and one posterior. This is confirmed by a study of Pander's figure (1856, pl. 2, fig. 22), as well as by my own experience with similar specimens. Some species belonging to this genus have previously been referred to *Dichognathus* Branson & Mehl, 1933.

Prioniodus alatus Hadding
Plate 22, figures 26, 28–34

Prioniodus alatus Hadding, 1913, p. 32, pl. 1, figs. 9, 10.

Holotype.—LO 2348 T, Hadding 1913, pl. 1, fig. 9; this paper, pl. 22, fig. 28. The impression of the holotype was found in Hadding's collections and is figured in this paper, pl. 22, fig. 26.

Diagnosis.—A *Prioniodus* with the small, slightly recurved anterior process provided with a few small denticles distally, the long, straight lateral process directed anteriorly, diverging at a high angle from the posterior process, and the long posterior process with a local, distinct expansion of the basal sheath on the inner side. Cusp rather small, denticles of the anterior and posterior processes numerous, not very small.

Description.—The basal cavity is deep and extends all along the processes. Along the anterior process it is but a groove, and along the lateral process it is narrow. The aboral margin, i.e., the margin of the basal sheath, is roughly parallel to the denticulate edges, with a minor convexity at the smooth outer side of the posterior process. At the inner side of the posterior process, the sheath flares out strongly anteriorly.

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The posterior process is by far the biggest. It is nearly straight. Its oral edge is slightly arched. The denticles are erect, stout, blunt and of varying sizes. They are fused basally. The anterior process is small. It is slightly recurved and strongly deflexed to the outer side, so that it may be hard to recognize it as anterior even by following its edge toward the point of the cusp. Distally, it carries a few inconspicuous denticles. For the rest, its edge is smooth.

The lateral process has almost taken the place of the anterior process. With the posterior process it makes an angle of about 135 degrees. It is quite straight. The denticles are erect, strong and not very sharply pointed. They are not fused basally to quite the same extent as on the posterior process.

The cusp is conspicuous but not very big. It may be slightly recurved. Its surface is longitudinally striated, whereas that of the processes is smooth.

Remarks.—In the Lower Ordovician *Limbata* limestone of south-central Sweden there occurs a *Prioniodus* (*P. navis* Lindström, 1954) that is rather similar to the present species. However, in *P. navis* (1) the denticles of the lateral process are weaker, (2) the anterior process is more definitely anterior and a little stronger, and (3) the lateral and posterior processes less widely divergent than in the present species. I have regarded the specimen (LO 2349 t) figured in Hadding's plate 1, figure 10 as belonging to *P. navis*. Herein, I was definitely wrong. The two specimens referred to *P. alatus* by Hadding obviously are conspecific.

Material.—Six specimens from Fågelsång E15, 30 specimens from the *Schroeteri* limestone of Öland.

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THE PERMIAN *EURYDESMA* FAUNA OF EASTERN ARGENTINA

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ABSTRACT—The marine invertebrates of the Pillahuinco group (Permian) of the southern hills of Buenos Aires (eastern Argentina) are described. The forms are principally pelecypods; two brachiopods and a few indeterminable gastropods are also found. Nine pelecypod species described as new are: *Stutchburia? argentinensis, Astartella? pusilla, Schizodus cycloliratus, Aphanaia? orbirugata, Liopteria dutoiti, L. bonaerensis, Eurydesma altum, Promytilus acinaciformis* and *Allorisma inflectoventris*. In addition, the Australian species *Eurydesma cordatum* and *E. hobartense* and the Indian form *E. mytiloides* are identified. The brachiopods include a new species, "*Chonetes*" *pillahuincensis*, and the Australian species "*Spirifer*" *darwini* for which the new genus *Notospirifer* is proposed. With the exception of *Astartella?*, found in the topmost beds of the Sauce Grande formation, and of indeterminable gastropods from the lower part of the Piedra Azul formation, the fossils are from the lower half of the Bonete formation, noted also for its *Glossopteris* flora remains. Elements in the Bonete fauna have close affinities with those of the lower and upper Marine series of New South Wales, Australia, usually regarded as Permian. They include the first *Eurydesma* remains known from South America.

INTRODUCTION

THE southern hills of Buenos Aires province, eastern Argentina, have long been known for their "Lower Gondwana" beds and their general resemblance to the Cape mountains of South Africa. The Lower Permian glacial conglomerates of the southern hills were discovered by Keidel in 1916 but Du Toit was the first to point out, in 1927, the close similarity between the lower Gondwana sequence of the hills and that of the Cape mountains. It was not, however, until 1933 that the first upper Paleozoic fossils were found in the region. These were plant remains belonging to the *Glossopteris* flora (Harrington, 1934). Soon after, poorly preserved pelecypods were found in the same beds by Keidel and Riggi but the first determinable invertebrates were collected in 1937 by Keidel and the writer. Since then the author has paid many visits to the southern hills and has gathered a representative collection of invertebrates which are here described for the first time. Some of these fossils, however, were mentioned by Keidel in 1939 and by the writer in 1942 and 1947. The author is indebted to Miss Helen Muir-Wood of the British Museum of Natural History for plaster-casts of the type specimens of "*Spirifer*" *darwini* and to Dr. K. Campbell of the University of Queensland for several Australian spiriferids. The photograps of the type specimens of "*S.*" *darwini* were obtained by Mr. William Wiles at Columbia University by courtesy of Prof. Marshall Kay. Argentine types have been deposited in the collections of the Department of Geology, University of Buenos Aires.

STRATIGRAPHIC DISTRIBUTION OF THE FOSSILS

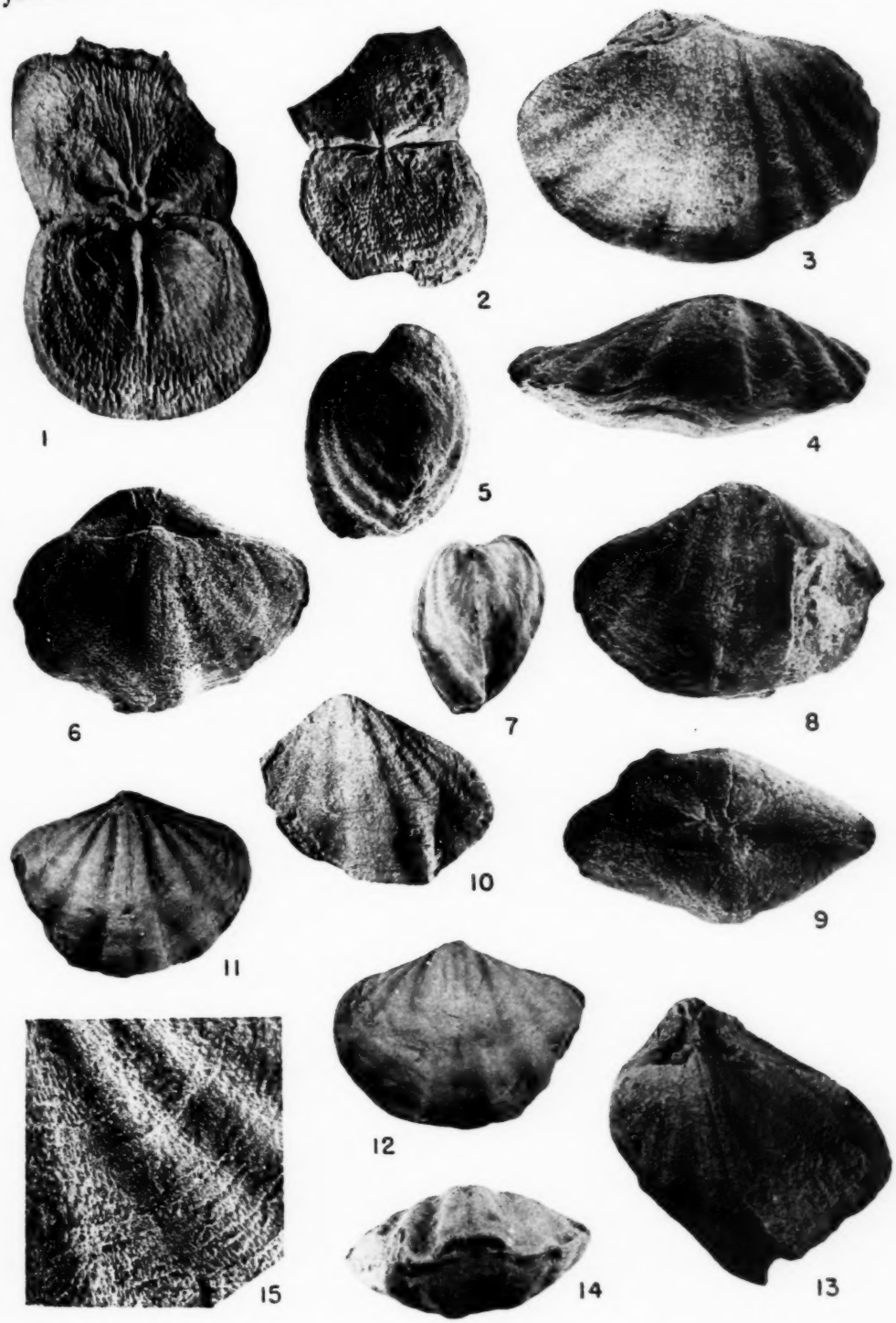
The name "Pillahuinco group" was applied by the writer, in 1934, to the upper Paleozoic beds of the southern hills of Buenos Aires.

EXPLANATION OF PLATE 23

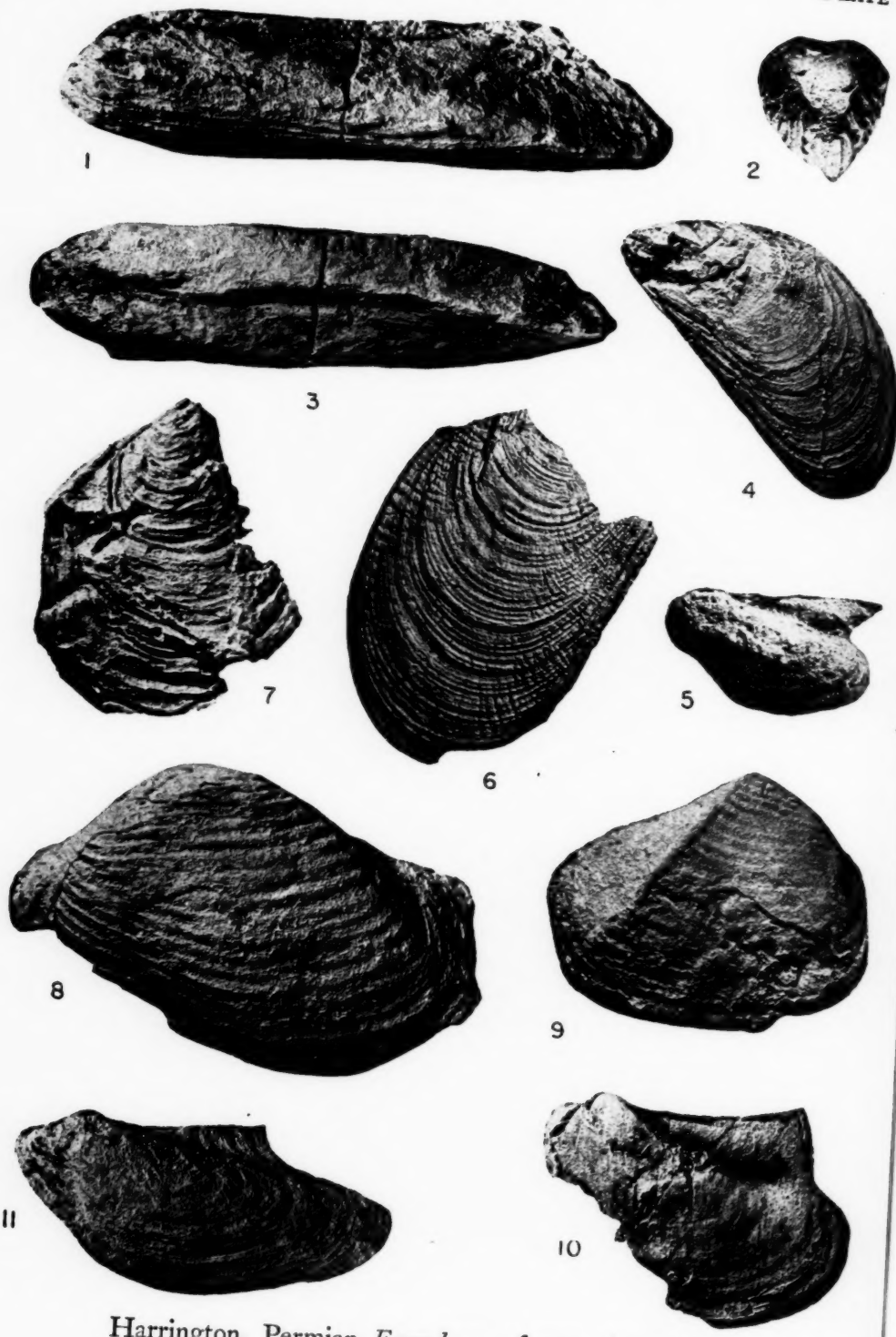
FIGS. *1–2*—"*Chonetes*" *pillahuincensis* Harrington, n. sp. *1*, Plasticine squeeze of holotype, 5772, ×3. *2*, Paratype, 5774, ×2. (p. 114)

3–6, 8–10, 13, 15—*Notospirifer darwini* (Morris). Argentine specimens. *3–4*, Dorsal and anterior views of 5811, ×2. *5, 6, 8, 9*, Side, dorsal, ventral and posterior views of 5820, ×2. *10*, Dorsal valve, *5777*, ×1.5. *13*, Dorsal view of 5775, ×2. *15*, Detail of sculpture, 5817, ×5. (p. 115)

7, 11, 12, 14—*Notospirifer darwini* (Morris), Australian specimen. Side, dorsal, ventral and anterior view of a plaster cast of the holotype, British Museum BB6243. nat. size. (Photographs by William Wiles) (p. 115)



Harrington, Permian *Eurydesma* fauna, Argentina



Harrington, Permian *Eurydesma* fauna, Argentina

The group, which is about 2300 metres thick, begins with glacial conglomerates conformably resting over Lower Devonian sandstones. It has been subdivided into four successive formations which, in ascending order, have been named Sauce Grande, Piedra Azul, Bonete and Tunas. The Sauce Grande is formed of about 900 metres of tillite and glacial conglomerate with thick intercalations of massive, fine grained, light green quartzite. The Piedra Azul consists of about 300 metres of bluish-black slaty shale with intercalations of yellowish sandstone and dark green mudstone in the upper part. The Bonete formation is about 400 metres thick and consists of an alternation of massive, fine grained, light green quartzite and massive, dark green mudstone. In the type locality there are 19 quartzite beds alternating with 19 mudstone layers. The Tunas formation consists of about 700 metres of dark green and purple shale with thin intercalations of yellowish sandstone and light green, very fine grained quartzite near the base.

Marine invertebrates are found in five main levels. The distribution of the fossils is as follows:

Level *5*. Bonete formation. Beds BM12 to BM16 (mudstone and quartzite); 30 metres thick; 1385 to 1355 metres above base of Pillahuinco group:
Eurydesma altum Harrington, n. sp.
E. mytiloides Reed
E. hobartense (Johnston)
Liopteria? bonaerensis Harrington, n. sp.
Schizodus cycloliratus Harrington, n. sp.
Promytilus acinaciformis Harrington, n. sp.

Level *4*. Bonete formation. Bed BM6 (mudstone and shale); 15 metres thick; 1285 to 1270 metres above base of Pillahuinco group:
"Chonetes" pillahuincensis Harrington, n. sp.
Notospirifer darwini (Morris)
Stutchburia? argentinensis Harrington, n. sp.
Allorisma inflectoventris Harrington, n. sp.
Aphanaia? orbirugata Harrington, n. sp.
Liopteria? dutoiti Harrington, n. sp.

Level *3*. Bonete formation. Bed BA1 (quartzite); 2 metres. Base of the Bonete formation, 1202 to 1200 metres above base of Pillahuinco group:
Eurydesma cordatum Morris

Level *2*. Piedra Azul formation. Lower shale, 75 metres thick; 1047 to 971 metres above base of Pillahuinco group:
Indeterminable gastropods

Level *1*. Sauce Grande formation. Uppermost transition beds; 5 metres thick; 900 to 895 metres above base of Pillahuinco group:
Astartella? pusilla Harrington, n. sp.

CORRELATION AND AGE

The fossil assemblage of the Bonete formation shows decidedly Australian affinities. The genus *Eurydesma* represents, in the marine peri-Gondwana environment, what the genus *Glossopteris* represents in the continental Gondwana compass, and the "*Eurydesma* fauna," as Washburne styled it, can be properly regarded as the marine counterpart of the "*Glossopteris* flora" of the southern continents.

Eurydesma, originally described from Australia and Tasmania, is also represented in India (Salt Range and Kashmir) and Southwest Africa. The Argentine occurrence extends the range of the genus to almost all the "peri-Gondwana" seas. Not only the genus but actually three Australian species have been identified in Argentina, namely *E. cordatum*, *E. hobartense* and *E. mytiloides*. *E. cordatum* is one of the most characteristic

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EXPLANATION OF PLATE 24

FIGS. *1–3*—*Stutchburia? argentinensis* Harrington, n. sp. Left, anterior and dorsal views of holotype, 5778, about natural size. (p. 117)

4, 6—*Promytilus acinaciformis* Harrington, n. sp. *4*, Left valve, holotype, 5785, ×1.5. *6*, Detail of the sculpture, right valve, paratype, 5786, ×2.5. (p. 126)

5, 11—*Liopteria? dutoiti* Harrington, n. sp. *5*, Left valve, paratype, 5782, ×2. *11*, Left valve, holotype, 5783, ×1.3. (p. 120)

7—*Aphanaia? orbirugata* Harrington, n. sp. Right valve, holotype, 5779, nat. size. (p. 121)

8—*Allorisma inflectoventris* Harrington, n. sp. Left valve, holotype, 5781, ×1.5. (p. 126)

9—*Schizodus cycloliratus* Harrington, n. sp. Plasticine squeeze of external mold of right valve, holotype, 5780, ×1.3. (p. 118)

10—*Liopteria bonaerensis* Harrington, n. sp. Internal cast of left valve, holotype, 5802, ×1.5. (p. 120)

species in the lower Marine series of New South Wales but in some localities, as in Ulladulla, it occurs in the upper Marine series associated with *E. hobartense* (Raggat and Fletcher, 1937, p. 154). *E. mytiloides*, originally described by Reed from the "*Eurydesma* zone" of the Talchir series of Kashmir and the Salt Range, is also frequent in the lower Marine series of New South Wales. In addition to these species, the endemic form *E. altum*, n. sp., seems closely related to *E. mytiloides*.

The remainder of the Bonete pelecypods are less characteristic but even so they show Australian alliances. *Stutchburia* is a typical Australian genus, also present in the Bonito group of Brazil and *Aphanaia*, known by two Australian species, has been recorded by Reed from the upper Dwyka beds of South Africa (1936b, p. 162). Licharew's (1934, p. 142) identification of *Aphanaia* from the Kolyma region of Siberia needs confirmation as, judging by Newell's remarks (1937, p. 77), the generic assignment seems rather doubtful.

The species referred to *Liopteria* may also be compared with Australian forms but *Promytilus acinaciformis*, n. sp., belongs to a more generalized and cosmopolitan stock. The genus *Allorisma* is also cosmopolitan and it seems to be well represented in the Permian of Australia. Some of the species assigned to *Sanguinolites* by de Konninck, such as *S. etheridgei* de Konn., *S. mitchelli* de Konn., *S.* ("*Pholadomya*") *undata* (Dana) and *S. tenisoni* de Konn. are in all probability true *Allorisma* even if Laseron refererd the first three species to the genus *Chaenomya* Meek.

Only one Argentine species seems to show "boreal" relationships. This is the shell identified as *Schizodus cycloliratus*, n. sp., The boreal affinities of this form, however, are by no means certain as the Argentine shell differs markedly from the typical boreal *Schizodus* in several important details.

The two brachiopods present in the Bonete fauna also show clear Australian relationships. "*Chonetes*" *pillahuincensis* n. sp. is not unlike *C. cracowensis* while *Notospirifer* ("*Spirifer*") *darwini* was originally described from the lower Marine series of New South Wales and is also known in the upper Talchir beds of the Salt Range.

The age of the Bonete fauna seems decidedly Permian but whether Lower or Middle Permian depends on whether we accept a Pennsylvanian or a Lower Permian age for the Sauce Grande glacials and its equivalents, the Dwyka of South Africa, the Talchir of India and the Lochinvar of New South Wales. In the present state of our knowledge the problem seems beyond objective solution. Since 1934 the writer has favored the view of a Lower Permian age for the glacial beds and this is also the opinion of many Australian and South American geologists. Those who adhere to this view would be inclined to regard the Bonete formation as more likely Middle Permian. Other "southern" geologists, however, and Du Toit among them, have proposed a Pennsylvanian age for the glacial deposits and this would bring the Bonete formation into the Lower Permian.

SYSTEMATIC DESCRIPTIONS

Phylum BRACHIOPODA
Family CHONETIDAE
Genus CHONETES Fischer de Waldheim
"CHONETES" PILLAHUINCENSIS
Harrington, n. sp.
Plate 23, figures 1, 2

Shells of medium size and general subcircular to subelliptical outline, transversely elongated and wider than long. Ventral valve gently convex. Dorsal valve flat or slightly concave. Hinge-line straight, shorter than the maximum width of shell which is measured subcentrally. Cardinal extremities obtusely rounded. Ventral beak inconspicuous, small and very slightly incurved.

None of the specimens show the external layers of the shell. The inner layers bear a marked radial sculpture consisting of fine radiating ridges and rows of tiny rounded pits. Near the anterior margin several ill-marked concentric corrugations are visible in some specimens.

The interior of the ventral valve shows short dental buttresses and a very conspicuous median septum extending forwards for about two-thirds the total length of valve. The large flabellate and quadruple muscle scar is divided into two symmetric halves by the median septum. The adductor muscle scars are weak, barely visible in some speci-

mens. They are narrow, elongated and fusiform, placed at each side of the septum and directly in contact with it. The diductor scars are larger and subtriangular-flabellate in outline.

Interior of dorsal valve with strong, well developed, raised cardinal process, laterally coalescent with short curural plates. Dental sockets deep, narrow, slitlike and oblique. In front of the cardinal process there is a small excavated platform, little raised over the bottom of the valve. The platform is prolonged anteriorly into three divergent and narrow ridges. The central one has the character of a true median septum, being as long as that of the ventral valve but more slender and less conspicuous. The two divergent lateral ridges are shorter than the median septum.

The adductor muscle scars appear as two small, elliptical, depressed areas at each side of the posterior third of the septum, laterally bounded by the divergent ridges. The diductor scars are much larger, placed between the ridges and the crural plates, and have a general subtriangular-ovoid outline.

The brachial impressions are very weak and barely distinguishable only in a few specimens. They have a reniform outline with a median inflexion and are not bounded by brachial ridges or keels.

The pallial region of both valves is covered by numerous elongated, raised and droplike pustules, irregularly distributed along radial lines.

The average length of the valves is 11.5 mm. and the average width 15.5 mm.

Remarks.—The specimens just described may be compared, as regards internal features, with *Chonetes hardrensis* Phillips as described and figured by Davidson (1863, pl. XLVII, figs. 14–16) from the Carboniferous of Great Britain. They are also similar in general outline and size to *C. cracowensis* Etheridge from the Permian of Australia (Etheridge, 1872, p. 336, pl. 18 fig. 2) but unfortunately no close comparison is possible as the internal characters of the Australian species remain unknown.

As the external features of the Argentine form are also unknown its correct generic position cannot be ascertained and, therefore, it is provisionally referred to *Chonetes* s.l

Locality.—Arroyo Piedra Azul, Sierra d Pillahuinco. Dark grey shale at the base of bed BM6, lower part of Bonete formation Permian. Numerous complete specimens.

Types.—Holotype, 5772; paratype, 5774.

Family SPIRIFERIDAE
Subfamily PHRICODOTHYRINAE
Genus NOTOSPIRIFER Harrington, n. gen.

Diagnosis.—Small, pauciplicate, lamellose-fimbriate spiriferids, in all probability bearing spines of *Phricodothyris*-type. Cardinal area short and triangular. Dental and crural plates well developed, divergent. Ventral septum absent. Dorsal septum thin, long, not continuous back to the umbo.

Type species.—*Spirifer darwini* Morris.

NOTOSPIRIFER DARWINI (Morris)
Plate 23, figures 3–15

Spirifer darwini MORRIS, 1845, in Strzelecki, p. 279.
Spirifer darwini (?) DANA, 1849, p. 684, pl. 1, fig. 7.
Spirifer undifera var. *undulata* ETHERIDGE, 1872, p. 330, pl. 15, fig. 3–5.
Spirifer strzeleckii DE KONNINCK (pars), 1877, p. 183, pl. 14, fig. 1–1a (non coetera).
Spirifer darwini JOHNSTON, 1888, pl. 12, fig. 6, 7 (?), pl. 13, fig. 4.
Spirifer strzeleckii JOHNSTON (pars), 1888, pl. 11, fig. 10 (non coetera).
Martiniopsis darwini WAAGEN, 1891, p. 131, pl. 5, fig. 9a–c.
Spirifer darwini ETHERIDGE, 1892, p. 238.
Martiniopsis darwini FRECH, 1898, p. 180, pl. 4, fig. 2a.
Spirifer darwini GIRTY, 1908, p. 347.
Spirifer (*Brachythyris*) *darwini* REED, 1932, p. 27, pl. 5, fig. 10–12.
Spirifer strezeleckii HARRINGTON (non de Koninck), 1947, p. 26.

The Argentine collection contains about 20 steinkerns of a small pauciplicate spiriferid which seem identical with those of "*Spirifer*" *darwini* Morris from the Permian of Australia. The identification of these shells has been made by actual comparison with plaster casts of the type specimens of "*S.*" *darwini*, kindly sent to the writer by Miss Helen Muir-Wood of the British Museum of Natural History. Morris' types have never been figured and the species only very briefly and inadequately described. The following description is based on the examination of the plaster casts of the two type specimens (steinkerns) from Glendon, New South Wales, kept in the

collections of the British Museum (Nos. BB 6243 and BB 6244, originally numbered 96869), complemented by observations made by Miss Muir-Wood on the actual specimens. The Argentine steinkerns agree very closely with the Australian specimens and display some details not clearly seen in Morris' type, but it has been thought better not to use them to complement the description of the Australian shells as this would only serve to confuse the issue. Their identification will be dealt with separately.

Description.—Shell of moderately small size, transversely elongated, subelliptical in outline. Length about three-fourths the width. Profile moderately biconvex, valves subequal in depth. Hinge-line short. Maximum width of valves measured about midway between anterior and posterior margins. Cardinal extremities rounded. Cardinal area small, triangular, concave, oblique to plane of valves. Ventral beak small, incurved.

Ventral valve with wide, shallow median sinus, uniformly widened towards anterior margin and projected anteriorly into a short U-shaped linguiform process. Bottom of sinus flat to very slightly convex, smooth. Lateral slopes with three costae, progressively decreasing in size towards lateral margins. Specimen BB 6243 shows faint indications of a fourth and smaller costa near the cardinal extremities. The lateral costae are rounded, wide and simple, being separated by shallow furrows of rounded bottom, about as wide as the costae.

Dorsal valve with a wide median fold bearing a shallow median sulcus, far less marked than the lateral furrows between the costae. It is quite distinct in specimen BB 6243 but only faintly visible in BB 6244. Lateral slopes with three costae similar to those of the ventral valve and very obscure indications of a fourth one near the cardinal extremities.

The steinkerns show concentric corrugations, more crowded near the anterior margin, which represent the borders of overlapping lamellae. Faint radiating striae may be seen even in some areas of the plaster casts.

According to Miss Muir-Wood (private letter, 13 May 1953) the actual specimens show "obscure traces of spines which must have covered the entire surface. I could not make out any details of the spines themselves."

The internal structures cannot be observed in the plaster casts but, according to Miss Muir-Wood (private letter, 31 July 1953) the ventral valve of specimen BB 6243 shows diverging dental lamellae while that of specimen BB 6244 is too decorticated and imperfect to show anything. The dorsal valve of BB 6243 "may have a low ridge, but it is very obscure," while that of BB 6244 shows "traces of two diverging plates extending from the umbo at an angle of about 45 degrees" and "traces of a narrow septal ridge not continuous back to the umbo."

Dimensions (*mm.*).—

	BB 6244	BB 6243
Length	25?	25
Width	32	35
Depth	20	18
Length of hinge-line	22	24
Anterior width of ventral sinus	13	10

Remarks.—In addition to the plaster casts of the two type specimens the writer has examined an external cast of an exfoliated dorsal valve from Mulbring, New South Wales, kindly sent by Dr. K. Campbell of the University of Queensland. This valve evidently belongs to Morris' species agreeing in all respects with the dorsal valves of the type specimens. It shows, however, traces of the exfoliated external sculpture, displaying a distinctly lamellose surface, the concentric lamellae being more evident near the anterior margin. The whole surface is covered with fine, short, raised striae ending at the borders of the successive lamellae and giving a fimbriate aspect to the shell. The sculpture is very similar to that displayed by exfoliated specimens of *Elytha*, *Phricodothyris* and *Torynifer* and this probably means that the valves had concentric rows of slender "double-barrelled" spines.

In 1877 de Konninck referred some Australian shells to *Spirifer darwini* and, at the same time, proposed the species *Spirifer strzeleckii*. In 1892, however, Etheridge pointed out that the shells identified by de Konninck as *S. darwini* did not agree with Morris' description and he regarded

them as probably a variety of *S. subradiatus* Sowerby. On the other hand, it is clear that at least part of the specimens referred by de Konninck to his *S. strzeleckii* truly belong to Morris' *S. darwini.*

Waagen, in 1891, and then Frech in 1898, referred *S. darwini* to *Martiniopsis* Waagen, but this generic assignment cannot be maintained as this genus has a smooth exterior with shallow fold and sinus but no costae or plicae on the lateral slopes.

In 1932 Cowper Reed had the opportunity to examine Morris' types while engaged in the study of a collection of fossils from Bren Spur, Kashmir, India, and though he made only passing references to the two Australian steinkerns he stated that the Indian specimens "completely agree with the two unfigured specimens of *Sp. darwini* from Glendon, N. S. Wales" (Reed, 1932, p. 27). The Bren Spur steinkerns show, just as the Australian ones, diverging crural plates and dorsal septum. Reed placed the species in *Brachythyris* McCoy but again this assignment cannot be maintained as this genus is multicostate (Harrington, 1939, p. 134).

"*Spirifer*" *darwini* seems to be a true Phricodothyrinae quite similar to *Elytha* Fredericks but differing from this Devonian genus in lacking a ventral while possessing a dorsal septum. It differs from *Torynifer* in lacking a ventral septum and from *Phricodothyris* in possessing dental plates and dorsal septum. Moreover, the external features of both *Torynifer* and *Phricodothyris* are quite different from those of "*Spirifer*" *darwini.* Under the circumstances it seems best to regard Morris' species as representing a new genus closely similar to *Elytha.*

The Argentine shells, also mostly steinkerns, are practically indistinguishable from the Australian type specimens. They are somewhat better preserved and show that the ventral beak is rather high and slightly overhanging the cardinal area. The surface of both valves—as seen in molds of exfoliated exteriors and in natural casts of exfoliated external molds—is distinctly lamellose-fimbriate and exactly comparable to the surface sculpture of the exfoliated dorsal valve from Mulbring. The ventral valves show short dental plates, reaching the bottom of the valve only in the umbonal region and diverging anteriorly at an angle of about 30–35 degrees. There is no ventral septum. The dorsal valves have short crural plates very similar to the dental plates of the ventral valves, of about the same length and diverging at a similar angle. The dorsal median septum is thin and long, reaching about midway between the posterior and the anterior margins, not continuous back to the umbo. Lastly, the shells are of about the same size as the Australian types though several are slightly smaller. It seems, therefore, that little doubt may be entertained regarding the identification of the Argentine shells.

Locality.—Arroyo Piedra Azul, Sierra de Pillahuinco. Bed BM6, lower part of Bonete formation. Permian. Eight steinkerns and 25 molds of exfoliated ventral and dorsal exteriors.

Illustrated specimens.—Holotype, BB 6243 (British Museum of Natural History). Argentine specimens: 5775, 5777, 5811, 5817 and 5820.

Phylum MOLLUSCA
Class PELECYPODA
Family SOLEMYIDAE
Genus STUTCHBURIA Etheridge
STUTCHBURIA? ARGENTINENSIS
Harrington, n. sp.
Plate 24, figures 1–3

Valves very transversely elongated, of general oval outline, four times longer than high, equivalved and very inequilateral. Valves convex, somewhat depressed posteriorly, closed. Dorsal margin straight and long. Its length is rather more than two-thirds the total length of the valves.

Umbones low, inconspicuous, little raised over the hinge-line, rounded, subanterior and prosogyrate. Anterior extremity strongly curved. Ventral margin straight or very gently convex. Posterior extremity more curved than the anterior. In one specimen an angular keel is observed running from the umbo to the posteroventral angle. The keel is more marked in the right than in the left valve and seems to be due to distortion and compression of the valves in a dorsoventral sense. It is not observed in the other specimens.

Surface covered with fine striae and concentric varices, without traces of radial

sculpture. Internal characters unknown.

Dimensions (*mm.*).—

Length	80
Height	20
Thickness	18 (exaggerated by compression)

Remarks.—The specimens just described seem to belong to *Stutchburia* Etheridge. They may be compared with the most transversely elongated representatives of the genus, especially as regards subanterior and prosogyrate umbones, straight dorsal margin and strongly curved extremities. The Argentine shells closely resemble those identified by Reed as *Stutchburia braziliensis* from the Permian of Brazil (Reed, 1930, p. 28, pl. 8, figs. 1–3), but they are even more transversely elongated than the Brazilian specimens. They are also slightly more convex and the umbones seem to be placed somewhat less anteriorly. In all other respects the two forms agree very closely and it is evident that they belong to the same genus. Their generic assignment, however, can be only provisional as the South American specimens are external molds while the genus *Stutchburia* is mainly based on internal features.

Localities.—Southeastern flank of Cerro Nortero, Sierra de las Tunas and Arroyo Piedra Azul, Sierra de Pillahuinco. Bed BM6. Lower part of Bonete formation. Permian. Four external molds.

Holotype.—5778.

Family PLEUROPHORIDAE
Genus ASTARTELLA Hall
ASTARTELLA? PUSILLA Harrington, n. sp.
Plate 25, figure 4

Shell somewhat transversely elongated, of general rounded-subtriangular outline. Height about four-fifths of total length. Apparently little convex (the holotype and only known specimen is rather crushed and compressed).

Umbones small, raised over hinge margin, slightly opisthogyrate, placed nearer to the anterior extremity at a distance equal to about two-fifths the total length of shell.

Anterior margin curved, almost semicircular. Ventral margin much less curved. Posterior margin short, oblique and arched. Postumbonal dorsal margin slightly curved. Anterodorsal angle rounded, very obtuse, barely distinguishable as a slight inflexion of the margin. Posteroventral angle rounded.

Exterior surface concentrically lirate. The lirae are regular, simple, separated by narrow angulate sulci. There are about seven lirae in 1 mm. near the ventral margin. Internal characters unknown.

Dimensions (*mm.*).—

Length	6.8
Height	5.5

Remarks.—The shell just described may be compared with *Astartella meridionalis* Thomas from the Upper Carboniferous (or Permian?) of Peru (Thomas, 1928, p. 231, pl. 7, figs. 5, 5a) especially as regards sculpture and posterior umbones, but the Peruvian species has straight and oblique posterior margin, acute posteroventral angle and mesogyrate (or even slightly prosogyrate) umbones. The Argentine specimen is also similar to some nonrostrate forms of *Leda*, such as *Leda* ["*Tellinomya*"] *clarkei* (de Konninck) from the Permian of Australia (de Konninck, 1898, pl. 3, fig. 8) with opisthogyrate and slightly anterior umbones. Our specimen, however, does not show even the slightest trace of the taxodont dentition which is clearly visible even in closed specimens of *Leda*. Accordingly, it seems best to regard it, at least provisionally, as representing a new species of *Astartella* Hall.

Locality.—Abra Fea, Sierra de las Tunas. Uppermost beds of the Sauce Grande formation. Permian. One closed specimen.

Holotype.—5824.

Family TRIGONIIDAE
Genus SCHIZODUS King
SCHIZODUS CYCLOLIRATUS Harrington, n. sp.
Plate 24, figure 9

Shell subtriangular-trapezoidal in outline, somewhat longer than high, gently convex. Umbo anterior, placed at a distance from the anterior extremity equal to one-third of the total length. Apex not preserved. Anterior margin uniformly curved, almost semicircular. Ventral margin much more gently curved. Posterolateral angle rounded, obtuse (about 110 degrees). Posterior margin almost straight, very slightly convex, directed vertically. Posterodorsal angle rounded, obtuse (about 115 degrees).

Flank separated from the siphonal area by a well-defined, rounded keel, directed obliquely from the apex to the posteroventral angle. The keel is almost straight but near its ventral end shows a very slight dorsal inflexion.

Flank covered by concentric lirae, evenly spaced and separated by wide and very shallow sulci. A total of 25 lirae are counted along the keel and in the central part of the valve there are five lirae in the space of 5 mm. In the umbonal area the lirae are directed from the keel obliquely forwards and downwards and bend suddenly upwards near the anterior margin. The lirae end at the keel and the siphonal area shows only extremely faint traces of these lirae in the posteroventral zone. The sculpture of the siphonal area, therefore, consists almost exclusively of very fine concentric striae, very close to each other, which do not pass over to the flank. These striae are, in all probability, nothing more than growth lines.

Dimensions (*mm.*).—

Length	ca. 37
Height	ca. 30
Thickness	ca. 4

Remarks.—The assignment of the species just described to the genus *Schizodus* King is not wholly satisfactory. This is partly due to the difficulty of conciliating opinions regarding the diagnosis of the genus and its variation range and also to the fact that the only specimen in hand does not show the structure of the hinge. Moreover, the peculiar concentric sculpture of this shell distinguishes it from the typical *Schizodus*.

By this last character it may be compared with *Myophoria praecox* Waagen from the upper *Productus* limestone of the Salt Range (Waagen, 1881, pl. 19, figs. 17–18) but in this species, which has been referred to the genus *Schizodus* by Newell (1940, p. 293, pl. 1, fig. 7), the keel is less marked and both the flank and the siphonal area bear equally conspicuous lirae.

Schizodus oklahomensis Beede, as described and figured by Newell from the Permian of Oklahoma (Newell, 1940, p. 291, pl. 1, figs. 1–6), is even closer to the Argentine species as it has a stronger keel and concentric lirae so faintly marked in the siphonal area as to be indistinguishable in Newell's photographs while they are plainly visible in the lateral flank. *Schizodus oklahomensis* is the only representative of the genus showing such a marked difference between the sculpture of the flank and the siphonal area and it is interesting to point out that Newell has expressed certain doubts regarding its true generic assignment.

The Argentine species differs from both the Indian and the American forms in the direction of the posterior margin which is subvertical instead of being directed obliquely downwards and backwards. It should be mentioned that in *S. oklahomensis* the margin is less oblique than in *S. praecox*.

Taking into account the direction of the posterior margin and the shape of the posterodorsal and posteroventral angles, the Argentine species may be compared with *Schizodus subquadratus* Grabau from the Permian of Mongolia (Grabau, 1931, p. 313, pl. 31, fig. 1), but this form lacks concentric lirae and has a longer posterior and less curved anterior margin. By its general outline it may be compared with an internal cast of a right valve from the Permian of Brazil identified by Cowper Reed as *Schizodus* sp. (Reed, 1930, pl. 7, fig. 2), but this specimen has a more oblique posterior margin and a somewhat more subcentral umbo.

As Newell has pointed out, following Cossmann and Crickmay, *Schizodus* seems to be exclusively Permian and, at the same time, the only genus of Trigoniidae represented in that period. All the Mississippian "*Schizodus*" and most, if not all, the Pennsylvanian ones belong to the genus *Protoschizodus* while all the Permian "*Myophoria*" heretofore described have turned out to be, upon closer examination, true *Schizodus*. Accordingly, the Argentine species is here referred to the genus *Schizodus* though it is possible that this form, as well as *S. oklahomensis* and *S. praecox* may belong, as already pointed out by Newell, to a new genus intermediate between *Schizodus* and *Myophoria*.

Locality.—Southeastern flank of the Cerro Nortero, Sierra de las Tunas. Lower part of the Bonete formation. Permian. One external cast of a right valve.

Holotype.—5780.

Family LIOPTERIIDAE
Genus LIOPTERIA Hall
LIOPTERIA? DUTOITI Harrington, n. sp.
Plate 24, figures 5, 11

Valves of general subovoid outline, very elongated transversely, gently convex and more than twice as long as high. Hinge-margin shorter than total length. Umbones placed very anteriorly, at a distance from the anterior extremity equal to one-sixth the total length of valves, little raised over the hinge margin.

Anterior ear very small. Posterior ear large, triangular, flat and depressed. Anterior margin short, strongly curved. Ventral margin bent in an ample, sweeping curve but with a small anterior inflexion located nearer to the posterior extremity than the umbones. Posterior margin strongly curved.

Surface covered by numerous concentric striae and growth lines.

Dimensions (*mm.*).—

Length	41
Height	18
Thickness	ca. 4

Remarks.—The Argentine specimens may be compared with those originally described by de Konninck as *Avicula sublunulata* from the Muree sandstone of Australia (1877, pl. 16, fig. 4). This species, as de Konninck himself later recognized (1885, p. 193) belongs in all probability to the genus *Liopteria* Hall. *Liopteria? dutoiti*, n. sp., differs from the Australian form in its greater height, form and position of the ventral inflexion, convexity of the ventral margin, more anterior position of the umbones and smaller anterior extremity. The generic assignment of the Argentine species is only provisional as the ligament is unknown. In general outline and external characters it may be also compared with some species of *Dozierella* Newell.

Locality.—Southeastern flank of the Cerro Nortero, Sierra de las Tunas, and Arroyo Piedra Azul, Sierra de Pillahuinco. Bed BM6. Lower part of the Bonete formation. Permian. Several external casts and internal molds of detached valves.

Types.—Holotype, 5783; paratype, 5782.

LIOPTERIA BONAERENSIS Harrington, n. sp.
Plate 24, figure 10

Valve of general ovoid-subtriangular outline, transversely and obliquely elongated, rather convex and somewhat swollen in the umbonal region. Height about two-thirds of the total length. Umbones placed very anteriorly, at a distance from the anterior extremity equal to one-sixth of the total length, little raised over the hinge margin.

Anterior ear very small. Posterior ear large, broad, triangular, flat and depressed, separated from the rest of the valve by a deep furrow (in the internal mold) extending from the umbo to the posteroventral angle. The furrow is gently curved and widens towards its distal end disappearing before reaching the margin.

Anterior margin moderately curved. Ventral margin more gently arched. Posterior margin apparently even less curved. Posterodorsal angle subrectangular.

Surface covered by concentric striae and growth lines, preserved only near the ventral margin.

Dimensions (*mm.*).—

Length	29
Height	20
Thickness	ca. 3

Remarks.—The valve just described differs from *Liopteria? dutoiti* in being proportionally shorter and higher and more convex, especially in the umbonal region. Its greatest affinities seem to lie with *Liopteria macroptera* (Morris) as described by de Konninck (1877, pl. 16, fig. 12) from the Permian of New South Wales, but no close comparison is possible. The deep furrow which in the internal cast separates the

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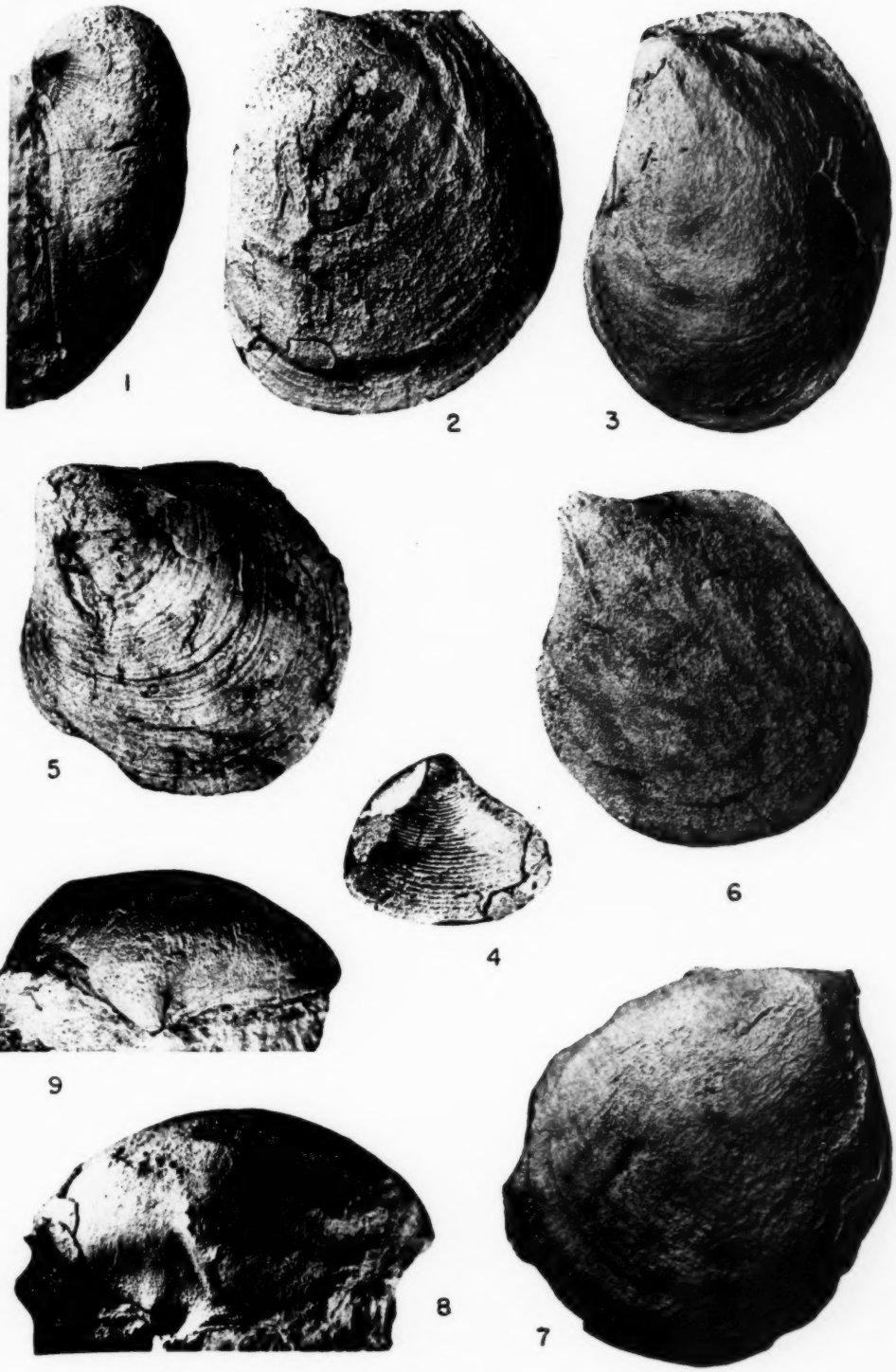
EXPLANATION OF PLATE 25

FIGS. *1–3, 9—Eurydesma altum* Harrington, n. sp. *1, 2, 9*, Anterior lateral and dorsal views of left valve, holotype, 5790, ×1.5. *3*, Internal cast of left valve, paratype, 5792, ×1.5. (p. 125)
4—Astartella? pusilla Harrington, n. sp. Left view of holotype, 5824, ×4.2. (p. 118)
5–8—Eurydesma mytiloides Reed. *5*, Plasticine squeeze of the external mold of a left valve, 5850, nat. size. *6*, Internal cast of left valve, 5795, nat. size. *7–8*, Lateral and dorsal views of the internal cast of a right valve, 5788, nat. size. (p. 124)



Harrington, Permian *Eurydesma* fauna, Argentina

Harrington, Permian *Eurydesma* fauna, Argentina

posterior ear from the rest of the valve sharply distinguishes this species.

Locality.—Southeastern flank of the Cerro Nortero, Sierra de las Tunas. Lower part of the Bonete formation. Permian. One internal cast of a left valve showing part of the original shell substituted by hematite.

Holotype.—5802.

Family MYALINIDAE
Genus APHANAIA de Konninck
APHANAIA? ORBIRUGATA Harrington, n. sp.
Plate 24, figure 7

Posidonia orbirugata HARRINGTON, 1947 (nomen nudum), p. 27.

A few deformed and fragmentary external molds of a fairly large pelecypod probably belong to a new species of *Aphanaia* de Konninck.

The valves are large, oval, slightly oblique and higher than long. The convexity of the shells cannot be ascertained as all the specimens have suffered severe flattening. The beaks are high, very anterior, pointed and slightly recurved. One fragmentary cast of an external mold of the umbonal region of both valves shows that the left beak is rather higher than the right and that, therefore, the shells were slightly inequivalve. The hinge-line is straight and long, its length being equal to about five-eighths of the total length of the valves. The anterior margin is not well preseved in any specimen. The ventral margin is evenly curved and grades into the posterior margin which becomes straight and oblique near the postero-dorsal angle. Posterior wing rather large, depressed.

Surface of the valves covered by numerous, concentric and fairly regular corrugations, separated by concentric sulci.

Dimensions (mm.).—

	Holotype
Height	broken (50?)
Length	ca. 42
Length of hinge-line	25
Thickness	flattened (4)

Remarks.—In 1947 the writer provisionally referred the form just described to *Posidonia* Bronn. At that time a single specimen was known but new material collected since shows that the provisional identification is untenable. The Argentine external molds and casts are closely comparable to *Aphanaia* de Konninck but no positive generic assignment is possible as this genus is mainly based on the character of the muscle scars, not seen in external molds.

Aphanaia? orbirugta, n. sp., may be compared with the type species, *A. mitchelli* (M'Coy) as described and figured by de Konninck (1898, p. 239, pl. 21, fig. 5) from the Permian of Australia. It differs from it in its longer hinge-line and shorter and more oblique posterior margin. The Argentine species seems to be somewhat less high than the Australian, but this is by no means certain as none of the specimens show their true height, all being broken ventrally.

Locality.—Arroyo Piedra Azul, Sierra de Pillahuinco. Bed BM6. Lower part of the Bonete formation. Permian. Five external molds and casts of detached valves and one cast of an external mold showing the umbonal region of both valves.

Holotype.—5779.

Family EURYDESMIDAE
Genus EURYDESMA Morris

The correct identification of the different species assigned to the genus *Eurydesma* Morris is a difficult problem, indeed, as it is clear that the genus has a wide range of specific variability and that the different species heretofore distinguished show an equally wide range of individual variation.

In 1910 Etheridge and Dun re-examined the Australian forms with a "synthetic" outlook and decided that only two species, *Eurydesma cordatum* Morris and *Eurydesma hobartense* (Johnston), are represented in Australia. Reed, on the other hand, described the Kashmir and Salt Range forms, in 1932 and 1936 respectively, with an "analytic" mind, distinguishing not less

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EXPLANATION OF PLATE 26

FIGS. *1, 4–7*—*Eurydesma hobartense* (Johnston). *1, 5*, Internal casts of left valve, 5787, ×1.5. *4, 6*, Lateral and dorsal views of an internal cast of a right valve, 5789, ×1.5 and nat. size. *7*, Internal cast of right valve, 5797, ×1.5. (p. 123)

2–3—*Eurydesma cordatum* Morris. Right and dorsal views of an internal cast, 5791, nat. size. (p. 122)

than eleven species and six varieties in the Indian localities. Fourteen of these forms were described from the Punjabian of the Salt Range. In 1944 Fossa Mancini expressed grave doubts regarding the validity of these 14 forms, judiciously stating that (Fossa Mancini, 1944, p. 91, translated by the writer):

> whoever would ask himself what paleobiologic and stratigraphic value should be attached to so many species and varieties, may find the answer in the fact that all of them proceed from the same locality and from the same stratigraphic level; a fact leading to suspect that they are simple individual variations shown by different specimens of a very polymorphous species. The differences between the shells figured and described by Reed are evident, but not greater than those which we are used to observe between different individuals of certain large species of living lamellibranchs as, for instance, *Ostrea edulis*.

Fossa Mancini's argument carries considerable weight as it is difficult to understand how so many closely related species and varieties of a single genus could have thrived together in close biological association.

Considerable confusion exists, furthermore, regarding several of the forms originally described from Australia. Etheridge and Dun, though admitting only two species, distinguished a variety of *Eurydesma cordatum* as var. *sacculus* Dana which obviously does not correspond to the form described by Dana as *Eurydesma sacculum*, which, in its turn, is clearly different from the species originally called *Eurydesma* ["*Pachydomus*"] *sacculus* by M'Coy.

Eurydesma globosa Dana and *Eurydesma elliptica* Dana, accepted as "bona fide" species by several authors, were considered by Etheridge and Dun as invalid synonyms of *E. cordatum* Morris. Reed, on his part, stated that the Indian specimens identified by Waagen as belonging to *E. globosa* and *E. elliptica* are not referable to any of these species but belong, at least in part, to his *Eurysdema cordatum* var. *mytiloides* which he considered identical with *E. cordatum* var. *sacculus* Etheridge and Dun (non M'Coy nec Dana). To make confusion more confounded, Reed added that the forms identified by Koken as *E. globosa* and *E. elliptica* not only do not correspond to Dana's species but are also different from the shells incorrectly identified as such by Waagen!

But yet another disturbing factor is found in the different opinions regarding the orientation of the shells for their description and illustration. Following Morris and Dana, most paleontologists have placed the shells in such a position that "the umbones, whether anterior, subanterior or subposterior, point upwards and forwards and are on the dorsal side" (Reed, 1936, p. 17). This orientation has been used by Waagen, Koken, Diener and Reed. Etheridge and Dun, however, placed the shells in such a position that the dorsal margin behind the umbones was always horizontal. This orientation, adopted by Reed in 1932 but dropped in his 1936 paper, will be followed here as it has the obvious advantage of being always easy to obtain without ambiguities. It may be pointed out, in this regard, that many of Reed's 1936 figures show a rather arbitrary orientation and that the shells could be rotated many degrees without departure from the established rule regarding the position of the umbones. In other cases, as in his figures of *E. punjabicum* (Reed, 1936, pl. 2, figs. 3, 4) it is difficult to reconcile his own statement of the orientation rules with the actual orientation of the specimens. In these figures, if the umbones were to point "upwards and forwards" it seems that the specimens should be rotated by about 45 degrees, thus introducing fundamental changes in the height and length of the valves. These figures are, in fact, oriented according to Etheridge and Dun's rule, with the posterior dorsal margin in horizontal position.

It should be apparent, therefore, that in the present state of our knowledge most specific identifications of *Eurydesma* are somewhat provisional and strongly tinged with subjective ideas.

EURYDESMA CORDATUM Morris
Plate 26, figures 2, 3

Isocardia (?) sp. SOWERBY, 1838, in Mitchell, pl. 2, figs. 1, 2.
Eurydesma cordatum MORRIS, 1845, in Strzelecki, p. 276, pl. 12.
Eurydesma elliptica DANA, 1847, p. 158.
Eurydesma globosa DANA, 1847, p. 158.
Eurydesma cordata DANA, 1849, p. 700, pl. 8, figs. 1, 1a.
Eurydesma elliptica DANA, 1849, p. 700, pl. 7, figs. 6a–d.

Eurydesma globosa DANA, 1849, p. 700, pl. 7, figs. 7, 7a.
Eurydesma sacculus DANA, 1849, p. 700, pl. 7, figs. 8a–c.
Eurydesma cordata JOHNSTON, 1888, pl. 18, figs. 16, pl. 19, figs. 1, 1a.
Pachydomus globosus JOHNSTON, 1888, pl. 18, figs. 1, 1a.
? *Pachydomus konnincki* JOHNSTON, 1888, pl. 18, fig. 3.
? *Myalina* (*Leiomyalina*) *antarctica* FRECH, 1891, p. 201, figs. 21–23.
Eurydesma cordata ETHERIDGE, 1892, p. 278.
Eurydesma cordatum ETHERIDGE & DUN, 1910, p. 71, pl. 17; pl. 18, fig. 1; pl. 19, figs. 3–5; pl. 20, figs. 2–5; pl. 21; fig. 1, pl. 22; figs. 3, 4; pl. 23, figs. 1–4; pl. 25, fig. 3; pl. 26, fig. 4.
Eurydesma cordatum var. *sacculum* ETHERIDGE & DUN (pars) 1910, pl. 24, figs. 1, 2 (non coetera).

The basal sandstone layer of the Bonete formation contains innumerable internal casts of a large pelecypod which seems indistinguishable from *Eurydesma cordatum* Morris. The casts are usually severely distorted and invariably represent complete and closed individuals.

The best specimens show that the shells are subcircular in outline, slightly longer than high, very convex and strongly inflated. The umbones are low, broad, obtuse, anterior and prosogyrate. The lunule is large, elongated, rather deep and sloping downwards in front of the umbones.

The dorsal margin is almost straight immediately behind the umbones, but it arches down near its distal end passing regularly into the semicircular rounded posterior extremity which sweeps down into the rounded ventral margin. This, in its turn, sweeps up regularly in front passing into the rounded and nonprojecting anterior end.

The hinge characters are not clearly seen in any of the specimens, but some of them show traces of a strong dental process and fold in front of the umbo.

The retractor muscle scars are conspicuous, forming a gently curved row extending from the apex along the anterior umbonal slope below the edge of the lunule. The right valve of the illustrated specimen shows a sharp ridge extending from the apex downwards along the anterior umbonal slope behind the retractor muscle scars and faint traces of yet another and shorter ridge, seen in the umbonal region behind the first ridge. These features, however, are probably not original but due to wrinkling of the specimens by compression.

Dimensions (*mm.*).—

	(Illustrated specimen)
Length	ca. 77
Height	71
Thickness	ca. 24

Remarks.—The specimens just described are closely similar to an internal cast illustrated by Etheridge and Dun as *Eurydesma cordatum* var. *sacculum* Dana (Etheridge and Dun, 1910, pl. 24, figs. 1, 2), the only noticeable difference being the somewhat less ventricose character of the Argentine shells. *E. cordatum* var. *ovale* Etheridge and Dun (1910, pl. 21, figs. 4, 5 and pl. 25, fig. 2), on the other hand, is much less inflated than our specimens.

It is worth while to point out that the internal cast illustrated by Etheridge and Dun as *E. c.* var. *sacculum* Dana does not agree with Dana's original description and figures of his *Eurydesma sacculus* (Dana, 1849, p. 700, pl. 7, figs. 8a–e) and, in all probability, should be directly referred to Morris' species sensu stricto. Furthermore, this cast does not seem to be cospecific with the specimen retaining the shell which Etheridge and Dun also identified as *E. c.* var. *sacculum* Dana (Etheridge and Dun, 1910, pl. 20, fig. 1). As already pointed out by Reed (1936, p. 19) this specimen probably belongs to *Eurydesma mytiloides* Reed.

Locality.—East of the confluence of Arroyo Gurubu with Arroyo Piedra Azul, Sierra de Pillahuinco. Bed BA1. Lowermost part of the Bonete formation. Permian. Numerous internal casts of complete, closed valves.

Illustrated specimen.—5791.

EURYDESMA HOBARTENSE (Johnston)
Plate 26, figures 1, 4–7

Pachydomus hobartensis JOHNSTON, 1888, pl. 16, fig. 2.
?*Eurydesma globosum* KOKEN, 1904, text-figs. 2–3.
Eurydesma hobartense ETHERIDGE & DUN, 1910, p. 74, pl. 21, figs. 4, 5; pl. 25, figs. 1, 2.
Eurydesma hobartense var. *bigener* REED, 1936, p. 19, pl. 1, figs. 1–3.
Eurydesma hobartense var. *rotundata* REED, 1936, p. 20, pl. 1, figs. 4–7b, pl. 2, figs. 5, 5a.
?*Eurydesma aequale* REED, 1936, p. 24, pl. 2, figs. 6, 7, 7a–b; pl. 3, fig. 7.

In the middle part of the Bonete formation there occurs a quite different form which seems to agree in all respects with *Eurydesma hobartense* (Johnston). Only internal casts of detached valves have been found so far and though they show considerable individual variations, it is easy to arrange them in a gradational series thus proving that they belong to a single, albeit rather variable species.

The shells are of medium size and their general outline varies from subcircular to somewhat ovoid and obliquely elongated. They are rather convex and usually somewhat inflated in the umbonal region.

The umbones are comparatively low, subpointed, little to moderately raised over the hinge margin, slightly prosogyrate and subcentral. The lunule is rather long and only moderately deep, sloping obliquely downwards in front of the umbones.

The hinge-line bends in an obtuse angle in front of the umbones and the dorsal margin behind the apex is straight and about as long as the lunule. Posterodorsal angle obtuse and well marked. In the ovoid specimens the anterior margin is more strongly arched than the ventral margin and the posterior end, but in the subcircular specimens the three margins are smoothly and evenly rounded.

The retractor muscle scars are arranged in a conspicuous and long row. Two or three tiny scars, sometimes coalescing into a short crest, are seen immediately behind the apex along the posterior umbonal slope. This short posterior row, or crest, runs almost parallel to the hinge-line, but on reaching the apex it sharply bends outwards almost at right angles and descends along the anterior umbonal slope in a sweeping curve behind the lunule. This long anterior row of scars usually resolves itself into three distinct rows with an "en echelon" disposition. In some specimens the scars are continued in a curved row of less distinct marks which sweeps round parallel to the ventral and posterior margins, ending in a large oval marking which probably represents the adductor muscle scar.

Dimensions (*mm.*).—

	Right valve	Left valve
Length	35	ca. 42
Height	41	42
Thickness	ca. 11	ca. 12

Remarks.—*Eurydesma hobartense* (Johnston) seems to be a highly polymorphous species and very probably the Salt Range "varieties" distinguished by Cowper Reed as *E. h.* var. *bigener* Reed and *E. h.* var. *rotundata* Reed (1936), p. 19, 20) are nothing more than individual variations shown by different specimens. *Eurydesma aequale* Reed (1936, p. 24, pl. 2, figs. 6, 7, 7a–b; pl. 3, fig. 7) is also probably identical with *E. hobartense*, the name being apparently applied to the more ovoid and obliquely elongated individuals.

Some of the internal casts in the Argentine collection, are particularly similar to some of the secimens identified by Reed as *E. h.* var. *rotundata* and *E. h.* var. *bigener*. Others, are practically indistinguishable from some specimens of *E. aequale* Reed, while yet others are intermediate between these forms. It is, therefore, obvious that in the present state of our knowledge all these forms should be best regarded as individual variations of a polymorphous species. This seems a more judicious procedure than to distinguish numerous local "varieties" of more than doubtful value.

Locality.—Upper Arroyo Piedra Azul and western slope of Cerro Bonete, Sierra de Pillahuinco. Bed BA13. Middle part of the Bonete formation. Permian. Numerous internal casts of detached valves.

Illustrated specimens.—5787, 5789 and 5797.

EURYDESMA MYTILOIDES Reed
Plate 25, figures 5–8

Eurydesma globosum WAAGEN (pars), 1891, p. 128, pl. 3, figs. 1, 2 (non coetera).
Eurydesma cordatum var. *sacculum* ETHERIDGE & DUN (pars), 1910, pl. 20, fig. 1 (non coetera).
Eurydesma cordatum var. *mytiloides* REED, 1932, p. 50, pl. 11, fig. 1–3b.
Eurydesma cordatum var. *mytiloides* REED, 1936, p. 18, pl. 3, figs. 1, 2.
?*Eurydesma pertenue* REED, 1936, p. 26, pl. 4, figs. 8–9 (and pl. 5, fig. 12??).

Associated with *E. hobartense* there occurs, in the middle part of the Bonete formation, another large species of *Eurydesma* which seems identical with the Kashmir form originally described by Cowper Reed as *E. cordatum* var. *mytiloides*. Most of the Argentine specimens are internal casts but one is a well-preserved external impression of a detached left valve.

The shells are suboval in outline, as high

as long, strongly convex but not globose. The umbones are subanterior, pointed, high, elevated over the hinge line, prosogyrate and slightly incurved. The lunule is elongated, broad, moderately deep in the umbonal region and sloping obliquely downwards in front of the umobnes.

The hinge-line bends almost at right angles in front of the umbones. The dorsal margin behind the umbones is straight and rather short, sweeping down into the long and gently arched posterior margin. The ventral margin is shorter and more strongly arched, sweeping up into the longer and less curved anterior margin.

The cardinal plate is thickened and the resilifer striated. The cardinal fold and dental process of the right valve are very prominent and strong.

The retractor muscle scars are conspicuous, extending in a slightly curved row from the apex downwards, along the anterior umbonal slope behind the lunule. In some specimens the row of scars shows a small but sharp zig-zag at its middle.

The external surface of the shell is covered by numerous, fine, concentric growth lines.

Dimensions (*mm.*).—

	Right valve	Left valve
Length	54	47
Height	55	47
Thickness	16	12

Remarks.—The specimens just described are practically indistinguishable from the shells identified by Reed as *Eurydesma cordatum* var. *mytiloides* Reed from Kashmir and the Salt Range (Reed, 1932, p. 50, pl. 11, figs. 1–3b and Reed, 1936, p. 18, pl. 3, figs, 1, 2). This "variety" is easily distinguished from *E. cordatum* Morris s.s. by its general outline which is vertically elongated instead of subcircular. Furthermore, *E. cordatum* is highly globose and ventricose, having a broad and deeply excavated lunule, its dorsal margin is much longer than in *E. c.* var. *mytiloides*, the umbones are much more raised and the hinge-line bends in a broadly obtuse angle.

In 1936 Reed suggested that his variety *E. c.* var. *mytiloides* could deserve specific rank. As this form can be easily distinguished from *E. cordatum* s.s. on purely morphological grounds it seems best to regard it as a separate species as no obvious advantage is attached to its being considered as a simple variety of *E. cordatum*.

As already pointed out, some of the Australian specimens identified by Etheridge and Dun as *E. cordatum* var. *sacculum* Dana (1910, p. 20 fig. 1) probably belong to *E. mytiloides* Reed and it seems quite likely that the small shells from the Salt Range described by Reed as *Eurydesma pertenue* Reed (1936, p. 26, pl. 4, figs. 8, 9, pl. 5, fig. 12?) are young individuals of *E. mytiloides*.

Locality.—Southern slope of the Cerro Nortero, Sierra de las Tunas and western flank of the Berro Bonete, Sierra de Pillahuinco. Bed BA13. Middle part of the Bonete formation. Permian. Numerous internal casts and one external impression of a left valve.

Illustrated specimens.—5788, 5795, 5850.

EURYDESMA ALTUM Harrington, n. sp.
Plate 25, figures 1–3, 9

Shell of medium size, of general ovoid outline, vertically elongated. Dorsal end shorter than ventral. Hinge-line abruptly bent at the umbones, almost at right angles.

Dorsal margin short and straight behind the umbones. Posterodorsal angle well marked, obtusely rounded (115–120 degrees). Posterior margin long and evenly rounded, sweeping down into the almost semicircular ventral margin. Anterior margin long, almost straight and vertical.

Valves strongly convex, somewhat globose in the umbonal region, with a wide cincture along the ventral and posterior margins. Shell greatly thickened at the umbones which are globose, high, very anteriorly placed, overhanging the lunule, incurved and prosogyrate. Lunule elongated, broad, cordiform, striated and rather deep.

External surface covered by numerous concentric growth lines and corrugations.

In the internal casts the valves appear much less convex and the umbonal region is not appreciably globose or inflated. The umbones appear rather pointed, directed obliquely forwards, little raised over the hinge line and less anteriorly placed. The posterodorsal angle is rounded but well marked and the posterodorsal area is large and depressed. The retractor muscle scars are faint and inconspicuous sometimes barely visible, forming a short row along the

anterior umbonal slope. Dental process and cardinal plate small and comparatively little developed.

Dimensions (*mm.*).—

	Holotype
Length	30.5
Height	36.5
Thickness	14.0

Remarks.—The shells just described bear some resemblance to *Eurydesma mytiloides* Reed, being comparable to the specimen with the shell-matter preserved figured by Etheridge and Dun as *Eurysdema cordatum* var. *sacculum* Dana (Etheridge and Dun, 1910, pl. 20, fig. 1) which, as already stated, probably belongs to Reed's species. This specimen, which is about four times larger than the Argentine shells, has much more prominent, incurved and overhanging umbones. Furthermore, the dorsal margin behind the umbones is arched and the posterodorsal angle is not differentiated, the dorsal margin passing gradually into the curved anterior end.

The internal casts also show marked differences with those of the Indian specimens of *E. mytiloides* and with the Argentine casts referred to this species. The valves appear much less convex and rather compressed in comparison, while the retractor muscle scars are inconspicuous and barely visible, the dental process and cardinal fold being weak and little developed.

Locality.—Southern slope of the Cerro Nortero, Sierra de las Tunas, and western flank of the Cerro Bonete, Sierra de Pillahuinco. Beds BM12 and BM13. Middle part of the Bonete formation. Permian. Numerous internal casts of detached valves and three well preserved detached valves showing the external features (the shelly matter being substituted by limonitic substances).

Types.—Holotype, 5790; paratype, 5792.

Family MYTILIDAE
Genus PROMYTILUS Newell
PROMYTILUS ACINACIFORMIS Harrington, n. sp.
Plate 24, figures 4, 6

Modiola acinaciformis HARRINGTON, 1947 (nomen nudum), p. 27.

Shell obliquely elongate, with terminal beaks. Anterior lobe very small, preserved in very few specimens (usually defaced). Umbonal ridge low, rounded, inconspicuous. Anteroventral byssal sinus well developed, broad, placed nearer to the anterior than to the ventral extremity. Angle α (Newell, 1942) about 45 degrees. Form ratio (length /height), 1.2.

Surface covered with strong, regular, concentric corrugations and finer striae. Some specimens show, in addition, a radial sculpture of curved, bifurcating striae, especially visible near the anteroventral margin.

Dimensions (*mm.*).—

Height	24
Length	29
Greatest dimension	33

Remarks.—The species just described agrees in all important respects with Newell's diagnosis of his genus *Promytilus*. It can be especially compared with *P. priscus* Newell from the Permian of Kansas (Newell, 1942, p. 40, pl. 1, figs. 1, 2, 5–7) which has a smaller form ratio (1.21) than the type species *P. annosus* Newell (1.31). It differs from this and from all other species of the genus in the small anterior lobe, inconspicuous umbonal ridge and especially in the external sculpture.

Locality.—Southeastern slope of Cerro Nortero, Sierra de las Tunas and northwestern flank of Cerro Bonete, Sierra de Pillahuinco. Beds BM12, BM14 and BM16. Middle part of the Bonete formation. Permian. Numerous external molds and casts.

Types.—Holotype, 5785; paratype, 5786.

Family PHOLADELLIDAE
Genus ALLORISMA King
ALLORISMA INFLECTOVENTRIS Harrington, n. sp.
Plate 24, figure 8

Shell transversely elongated, subovoid, height about two-thirds of length. Lateral region of the valves slightly more convex than the posterodorsal area. Umbones broad, prominent, rounded, incurved, opisthogyrate and anterior, placed at a distance from the anterior margin equal to one-third the total length of shell.

Dorsal margin inflected behind the umbones, forming a concave and elongated area. Lunule apparently absent. Valves

probably somewhat gaping posteriorly.

Anterior margin strongly curved, semicircular. Ventral margin more gently curved. with a weak anterior inflexion placed immediately in front of a vertical from the umbones. A wide, shallow and ill-defined sulcus originates at the anterior part of the umbones and ends at the ventral inflexion, having an almost vertical direction. Posterior margin very gently curved. Postero dorsal angle rounded, obtuse. Posteroventral angle rounded, subacute.

Surface of valves covered with well defined, low concentric ridges separated by wide and shallow concentric sulci.

Dimensions (mm.).—

Height	29
Length	46

Remarks.—The species just described seems to fall within the range of the genus *Allorisma* King even if it is unknown whether the shell was granulated or not. The Argentine specimens may be compared with a fragmentary left valve from the Permian of Brazil identified by Reed as *Allorisma* sp. (1930, p. 33, pl. 7, fig. 4), which shows a ventral inflexion and an anterior "sulcus." The ornamentation, however, is rather different as the concentric ridges are wider, less numerous and more spaced. Moreover, the Brazilian shell shows faint radial striae in the posteroventral region and, therefore, approaches *Pholadomya*. *Allorisma? albequus* Beede from the Permain of Oklahoma (Newell, 1940, p. 296, pl. 2, figs. 8, 22, 23) is much smaller than our form, has more anterior umbones and less marked sculpture. *Allorisma baldryi* Thomas from the Pennsylvanian of Peru (Thomas, 1928, p. 222, pl. 8, fig. 1) has an external sculpture very similar to that of the Argentine specimens, but the general outline of the shell is quite different.

Locality.— Arroyo Piedra Azul, Sierra de Pillahuinco. Bed BM6. Lower part of the Bonete formation. Permian. Three casts of external molds of detached valves.

Holotype.—5781.

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REVIEW OF THE PLIOCENE BEAVER *DIPOIDES*

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ABSTRACT—The Pliocene beaver *Dipoides* is known from both North America and Eurasia. It is therefore a useful form in the intercontinental correlation of stratigraphic units. Large collections of this beaver from Oregon show the variation of characters of the occlusal pattern (formerly believed to be of specific rank) to be intraspecific. Species though may be typified by the difference in frequency of occurrence of particular occlusal patterns. Other characters (morphology of lophs, flexi) are useful in making diagnoses of species. Relative hypsodonty may be a useful character in determining phylogenetic lines.

One new species, *Dipoides smithi*, is described.

INTRODUCTION

THE McKay Reservoir local fauna of Oregon includes a large rodent representation. It occurs about 6 miles south of Pendleton, Oregon, on the east bank of the reservoir in a series of tuffaceous sandstones. Description of the remainder of the fauna is now in preparation for publication.

Dipoides is represented at McKay Reservoir by numerous teeth, mandible fragments, skull fragments and skeletal elements. Other species of this beaver are known from both North America and Eurasia. The relationships between these species are obscure in the existing literature. Fortunately materials so far described have been distinct. Confusion based on unrecognized synonymy therefore is at a minimum. Detailed examination shows that the materials collected at McKay Reservoir show a diversity of occlusal pattern and that collections representing other species show a similar diversity. These intraspecific variations may be confused with interspecific and intergeneric differences. In order to determine the taxonomic position of the McKay Reservoir material, it was necessary to try to gain some understanding of these variations and their phylogenetic taxonomic significance. Materials representing all North American species were examined (with exception of *D. rexroadensis* Hibbard which may be of another genus).

Complete collections from type localities of several species were available. These, along with the sample from McKay Reservoir, furnished material for a study of variations. Milk teeth, unworn, and little worn permanent teeth were frequently present, which allowed a broader understanding of the variations in occlusal pattern due to the possibility of determining variation in the course of wear. Study of these species demonstrated to the author the necessity for discriminate morphological description of the lophs and flexids (= flexi). Most original descriptions include only occlusal pattern description with little or no designation of the configuration of lophs and flexi. The variation in occlusal pattern tends to negate a description based largely on this character alone. Description of the lophs and flexids of known species has been added to make possible comparisons on this basis. Terms used in these additions are defined below. Measurement of materials using a standard method was also necessary due to the increased variation added by various methods of measurement formerly employed. These standard measurements are also described below.

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TERMS USED IN MORPHOLOGIC DESCRIPTIONS

Stirton's (1935) terminology is applied here. A review of these terms is included in figure 4 A, B, D, L and figure 3 A, G.

Loph is a general term applied here to the individual folds of the common "S" pattern. The first fold is referred to as anterior loph, the last is posterior loph and connecting is the median loph. When the parastriid is present in lower premolars, for instance, splitting the anterior loph or producing two separate anterior lophs, these are labeled first (anterior one) and second (posterior one) anterior lophs. These are used for the purpose of this study and are not intended as new terms.

Inflated or *uninflated* are terms to describe the configuration of the loph itself. When anterior and posterior faces are nearly parallel the loph is considered uninflated. When the anterior and posterior faces are convex outward the loph is said to be inflated.

Crescentic—Crescentic lophs are those which have a decided over-all curvature usually concave anteriorly except in posterior lophs.

Chevron—When the apex of the crescent is angular the loph is referred to as chevron.

Flexi or *flexids*—Stirton includes these in his original terminology. They may be described in a general way as the involutions between folds. The shape of these is described in the same way as lophs. A flexid or flexus is said to *abut* when the enamel of the flexid or flexus touches the enamel of the opposite side of the tooth. The distal end or termination of the flexid or flexus is described as *flattened*, *rounded* or *narrowed*. Flattened flexid ends are those which have broad ending with rather angular connections with the sides of the flexid. These may be expanded also. Rounded ends are those in which the flexid distal end is rounded off without narrowing of the flexid. Narrowed flexids are those which have an appearance of being drawn out or as the term says, narrowed, usually with a round termination. Termination and end are used interchangeably.

Striae or *striids* (see Stirton) are the grooves on the side of the tooth marking the external opening of the flexi and flexids. There is usually a flexus or flexid accompanying striae and striids but this is not always apparent when the flexid or flexus is very short.

Other terms used are self-explanatory or may be found in common usage in the existing literature.

STANDARD MEASUREMENTS EMPLOYED

Standard measurements are used in order to reduce measuring error as much as possible. Comparison with other works must allow for differences in measuring technique. A test of various measurement methods described in other studies of *Dipoides* shows differences up to 25 per cent are possible due solely to method of measurement. Measurements of the teeth were made on the column of the tooth just below the occlusal surface, not the occlusal surface itself. Actually the tooth column of *Dipoides* is very nearly the same size at the top as at the bottom in adults. Posterior-anterior dimension of the tooth is measured parallel to a line of paraconid-metaconid-mesoconid-entoconid and at right angles to the tooth column. The transverse measurement is the greatest diameter of the column at right angles to the posterior-anterior measurement. Abbreviations used are: posterior-anterior measurement PA, and TR, transverse measurement. Length is the greatest measurement in a straight line of the tooth column, abbreviated L.

SYSTEMATIC DESCRIPTIONS

DIPOIDES SMITHI Shotwell, n. sp.
Text-figures 1–3, 6E, F

Holotype.—Left lower jaw with incisor, P4-M2 and alveolus for M3, condyle missing from the ascending ramus; UOMNH F-4072.

Paratypes.—Palate P4's-M2's, UOMNH F-2820. Figure 1 B. Lower jaw with ascending ramus P4-M2, UOMNH F-2821.

Additional material.—Eleven lower jaws, 10 P_4, 19 lower M's, 4 P^4, 13 M^1-M^2, 5 M^3, one fragment of a skull. Complete and fragmental femora, astragali, vertebrae, tibia, and calcanea.

Type locality.—McKay Reservoir.

Diagnosis.—Hypsodont cheek teeth, no parastria on upper molars and upper premolars in adults, parastriid present infre-

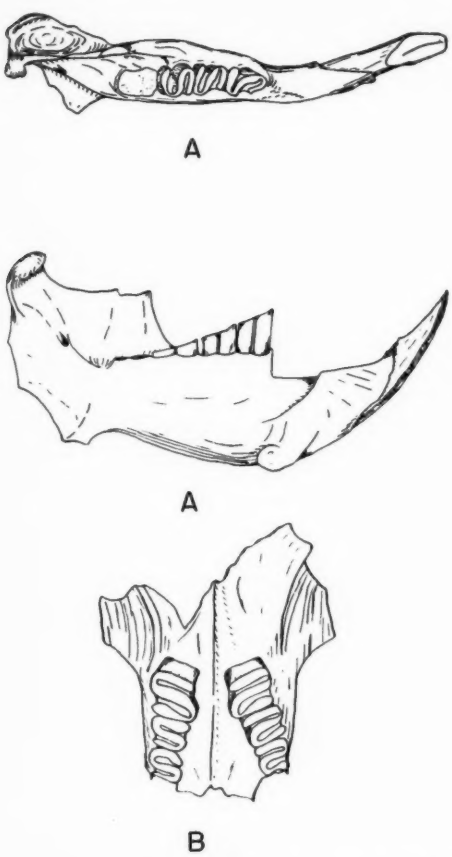

FIG. 1—*Dipoides smithi* Shotwell, n. sp. *A*, Holotype left lower jaw, incisor, P4-M2; UOMNH F-4072. Occlusal and lingual views, ×0.9. *B*, Paratype, palate, P4's-M2's; UOMNH F-2820. Occlusal view, ×0.9.

quently on lower premolars. All adult teeth have the S-pattern except the lower fourth premolar, which may not at times due to the presence of the parastriid. All the permanent teeth examined are rootless.

Named in honor of the late Dr. Warren D. Smith.

Description.—Upper jaw. Upper premolars and molars have the "S" pattern. Premolar is the largest tooth of series. The posterior fold of third molar is often an isolated enamel tube. Posterior palatine foramen is opposite the posterior margin of M_1. The incisor is nearly trapezoidal in cross-section with a convex enamel face.

Lower jaw. Lower premolars and molars display the "S" pattern except in rare instances when premolar has a parastriid. In adults the lower molars all display the "S" pattern and are nearly equal in size. The lower incisor is sharply triangular in cross-section with a convex enamel face. It is less recurving than the upper. A paratype exhibits a nearly complete ascending ramus which was heretofore unknown in *Dipoides*. It is similar to *Castor* but with a relatively larger masseteric crest and a broader pterygoid shelf. The complete femur resembles that described as *D. stirtoni* by Wilson (1934) but is slightly smaller. Several tibia fragments are included in the material, one being nearly complete. They are also similar to *D. stirtoni*.

Upper dentition. Premolar: Anterior loph flattened with anterior and posterior faces parallel, not as wide as medium loph. Median loph faces parallel; curves posteriorly. Posterior loph pendulous, projects out to even with labial border of tooth. Paraflexus present only in early stage of wear. Hypoflexus opens posteriorly, distal end rather wide and rounded, abuts with outer enamel. Mesoflexus nearly transverse with posterior bending at distal end; narrows at distal end, abuts against outer enamel.

M1 and M2: Smaller than premolar. Anterior loph slightly inflated, as wide as medium loph, differentiating it from the premolar. Median loph as in premolar. Posterior loph smaller than that of premolar, not as inflated as that of premolar. Hypoflexus similar to premolar. Mesoflexus does not narrow distally as in premolar but curves posteriorly.

M3: Posterior loph varies; may roll up on itself with the metaflexus bifurcating distally, one branch continuing transversely, the other following the rolling of the fold (fig. 3). In other cases the posterior loph is completely isolated as an enamel tube forming a stria and flexus not in Stirton's (1935) terminology; it is here referred to as the mediflexus with a medistria (fig. 3).

In P4-M2 the enamel is often broken through on the opposite side from the base of a flexus. Termination of mesoflexus is usually flattened. Termination of hypoflexus is pointed.

Lower dentition. Premolar: First anterior loph, when present, lenticular; second

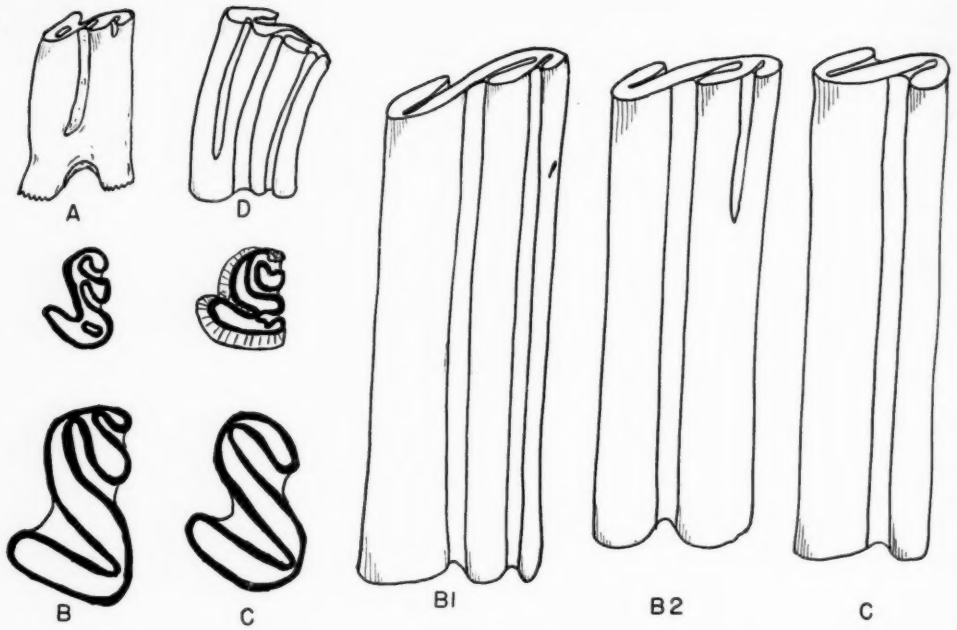

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FIG. 2—*Dipoides smithi* Shotwell, n. sp. *A*, Left DP_4, UOMNH F-3871; occlusal and lingual views. *B*, Left P_4; occlusal view. B1, Left P_4; lingual view illustrating complete parastriid. B2, Left P_4; lingual view illustrating incomplete parastriid. *C*, Left P_4; occlusal and lingual views illustrating lack of parastriid. *D*, Little-worn left P_4, UOMNH F-3869; occlusal and lingual views.

always present, bent distally, directed posteriorly. Median loph somewhat inflated, nearly isolated. Posterior loph crescentic, slightly inflated. Paraflexid short, directed slightly anteriorly, does not abut. Parafossetid present in some state of wear. Termination of paraflexid rather bulbous. Mesoflexid rather straight, diagonal, with curve towards transverse; abuts against opposite enamel which is often broken through; often diamond shaped. Metaflexid, termination narrowed, rounded; present only in little worn specimens; constricted at opening, bifurcated at end, meets hypoflexid nearly squarely. Hypoflexid opens anteriorly, straight, abuts against opposite enamel, or may curve forward. Termination narrowed with rounded end.

M1 and M2: Anterior loph slightly crescentic, nearly as large as posterior loph. Median loph lenticular, inflated. Posterior loph crescentic. Paraflexid present only in little worn specimens, Y-shaped in M1 and bent anteriorly in M2. Mesoflexid opens posteriorly, abuts, termination nearly as broad as rest of flexid with rounded end. Metaflexid not apparent, appears as fossetid to start with (see fig. 3 E).

DIPOIDES WILLIAMSI Stirton

Dipoides williamsi STIRTON, 1936, Jour. Mammalogy, vol. 17, pp. 279–281.

Type specimen, from the White Cone formation, Hopi County, Arizona, consists of lower jaw with P4-M3, the incisor being broken at the alveolus. P4 and molars have "S" pattern. No parastriid is present on the lower premolar of the type. One upper molar is known. *D. williamsi* is smaller than *D. stirtoni* and *D. smithi* and about the size of *D. wilsoni* (see table 6).

Upper dentition. M1 and M2: Anterior loph strongly crescentic. Posterior side has a sinus which nearly bisects it. Median loph inflated anteriorly, flattened posteriorly. Posterior loph evidently much flattened, damaged in only specimen known. Mesoflexus narrow, trends slightly posteriorly.

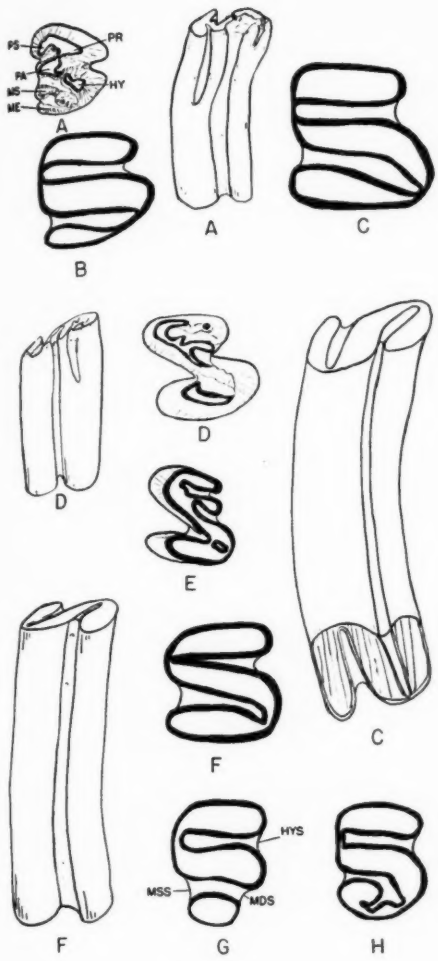

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FIG. 3—*Dipoides smithi* Shotwell, n. sp. *A*, Little-worn upper right molar, UOMNH F-3810; occlusal and lingual views. HY = hypocone, ME = metacone, MS = mesostyle, PS = parastyle, PR = protocone, PA = paracone. *B*, *C*, Two upper right molars. *D*, Little-worn lower left molar (M1?), UOMNH F-3872; occlusal and lingual views. *E*, Slightly worn lower left molar (M2 in lower jaw UOMNH F-2239); occlusal view. *F*, Adult lower left molar; occlusal and lingual views. *G*, Adult right M^3, UOMNH F-2659; MSS = mesostria, HYS = hypostria, MDS = medistria. H, Adult right M^3, UOMNH F-2470.

abuts against opposite side. Hypoflexus crescentic, has sinus on anterior face extending into anterior loph, abuts against opposite side.

Lower dentition. P4: Anterior loph lenticular, directed nearly anteroposteriorly, some posterior flattening. Median loph flattened anteriorly, slightly inflated posteriorly. Posterior loph flattened anteriorly, inflated posteriorly. Paraflexid does not reach opposite side, directed slightly anteriorly. Mesoflexid directed somewhat transversely with an anterior curve near end, does not abut. Hypoflexid nearly transverse, does not abut.

M1 and M2: Anterior loph very small. Median loph teardrop-shaped. Posterior loph crescentic. Mesoflexid narrow, opens posteriorly, may abut. Hypoflexid somewhat open, almost transversely, abuts.

DIPOIDES STIRTONI Wilson
Text-figures 4, 5, 6 G

Dipoides stirtoni WILSON, 1934, Carnegie Inst. Washington Pub. No. 453, pp. 19–28.

Originally described from Hemphillian beds near Rome, Oregon (CIT loc. 62), this is a large species similar in size and height of crown to *D. smithi* (table 2), characterized by very persistent parastriid and parastria in premolars. Discussion of variation in these teeth appears in the section on variation of characters of the teeth of *Dipoides*. The morphology of lophs and flexids is as follows:

Upper dentition. P4: Anterior loph rounded on anterior face. Shape varies greatly but anterior and posterior boarders nearly parallel in most specimens. Median loph crescentic, largest loph ends often squared; little or no inflation. Posterior loph teardrop-shaped. Paraflexus opposite hypoflexus, may or may not be separated by an isthmus (fig. 4 K, L). When isthmus is lacking, the two flexi join, isolating the anterior loph. Hypoflexus overlaps when isthmus is present. Terminations constricted and somewhat pointed. Mesoflexus crescentic, ends of crescent about even; abuts against enamel on opposite side. Terminations may be flared and flattened. Sometimes bent anteriorly (see Wilson, 1934, fig. 4, 5 for photos of these). Metaflexus narrow at opening but becomes bulbous distally, end curves posteriorly. Hypoflexus long, narrow, trends anteriorly; end rounded to almost bulbous. Flexus straight.

M1 and M2: Anterior loph slightly cres-

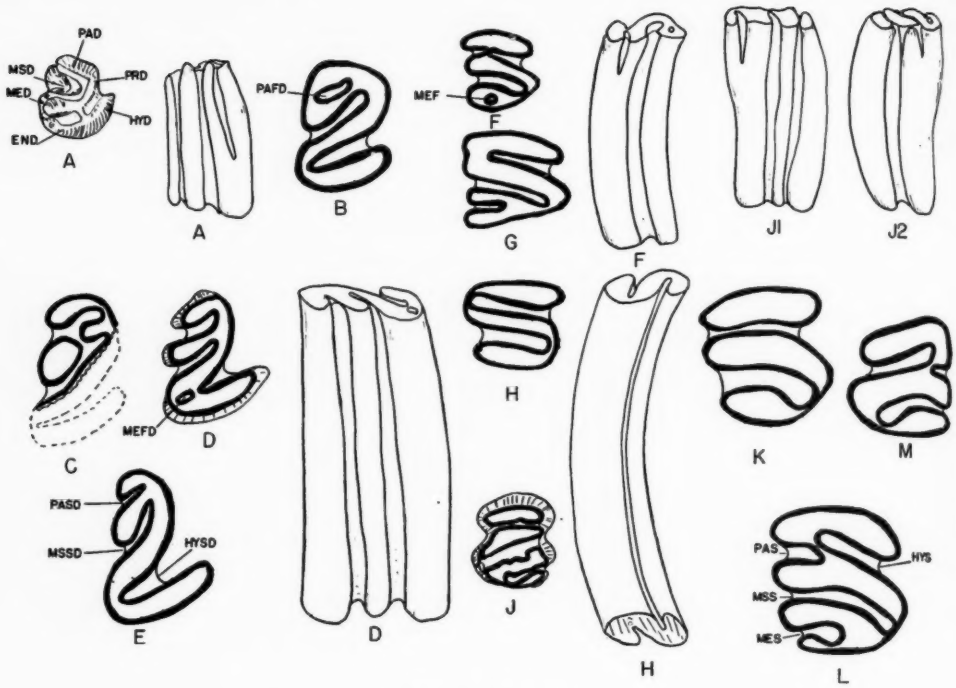

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FIG. 4—*Dipoides stirtoni* Wilson. *A*, Unworn right P_4, CIT collection; occlusal and lingual views; PRD = protoconid, PAD = paraconid, MSD = mesostylid, MED = metastylid, HYD = hypostylid, END = entoconid. *B*, Adult left P_4; bottom of tooth with incomplete parastriid, illustrating parafossettid (PAFD) ending of complete parastriid. *C*, Adult right P_4 fragment illustrating isolated mesostylid. *D*, Little-worn right P_4, illustrating metafossettid (MEFD) in little-worn specimens; occlusal and lingual views. *E*, Typical adult right P_4; PASD = parastriid, MSSD = mesostriid, HYSD = hypostriid. *F*, Little-worn upper right molar illustrating metafossette (MEF) in young individuals (same tooth as Wilson, 1934, fig. 8a). *G*, Little-worn upper right molar illustrating metastria in young adults. *H*, Typical adult upper right molar. *J*, Little-worn left P^4, occlusal view; note isolated anterior loph. *J1*, Labial view of *J*, *J2*, Lingual view of *J*. *K*, Adult right P^4 (same tooth as Wilson, 1934, fig. 4), CIT 1695. L, Adult right P^4 (same tooth as Wilson, 1934, fig. 3), CIT 1695; PAS = parastria, MSS = mesostria, MES = metastria, HYS = hypostria. *M*, Adult left P^4.

centic, inflated anteriorly, large. Median loph slightly inflated, goes directly across tooth. Posterior loph small, inflated. Paraflexus only in young individuals, short, not very open, abuts squarely against hypoflexus. Mesoflexus slightly crescentic to chevron, abuts against opposite enamel; end broad to flattened. Metaflexus present only in young individuals, becomes metafossette early in wear. Hypoflexus narrow, directly across tooth, does not abut against opposite side; terminations rounded.

M3: None seen, one illustrated by Wilson (1934, fig. 1) could not be found. CIT 1687.

Lower dentition. P4: Second anterior loph, may be long, pendulous, or bulbous; mesostylid sometimes an isolated cylinder (fig. 4 A, C). Median loph crescentic to straight, not inflated. Posterior loph sometimes slightly inflated. Paraflexid horizontal or may tend anteriorly, may or may not reach enamel; parafossetid in latter wear (fig. 4 B). Mesoflexid directed diagonally does not abut. Metaflexid apparently only in young individuals, becomes metafossettid with wear (fig. 4 D). Hypoflexid sharply triangular, narrow at extremity, does not abut. DP4 similar to *D. smithi* but metafossettid is divided into three lakes in some specimens.

Molars: Anterior loph narrow, slightly pendulous, slightly crescentic, as large as

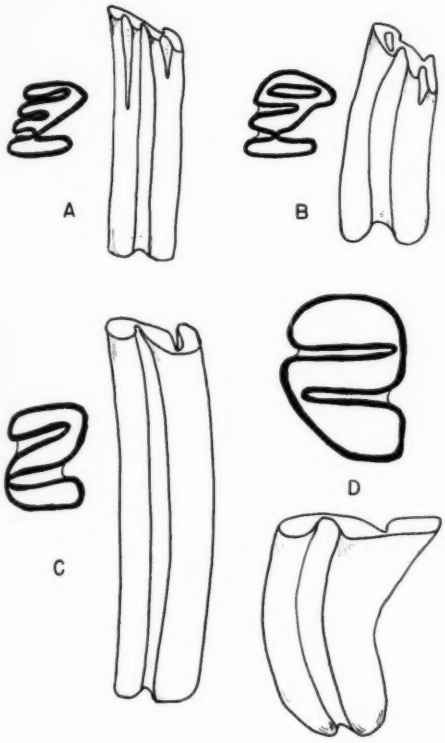

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FIG. 5—*Dipoides stirtoni* Wilson. *A*, Little-worn lower right molar. *B*, Little-worn lower right molar, CIT 1693. *C*, Adult lower right molar. *D*, Well-worn lower right molar.

posterior loph. Median loph narrow, sides parallel. Posterior loph narrow. Paraflexid only in slightly worn specimens, narrow horizontal. Parafossettid present in later stages of wear. Neither paraflexid nor parafossettid remain in M1 or M2 on appearance of permanent P4. Mesoflexid narrow, directed anteriorly, does not abut; termination rounded. Metaflexid present only in slightly worn specimens, abuts severely with hypoflexid, opens posteriorly. Hypoflexid narrow but slightly open at proximal end, abuts, directed posteriorly; termination rounded. A wear series of variation in the lower molars of *D. stirtoni* are shown in figure 5.

DIPOIDES cf. D. STIRTONI Wilson
Text-figure 6 A-D

Earlier citations appear in Wilson (1934) and Stirton (1935); known materials from the Rattlesnake formation of Oregon include the following: right lower jaw fragment with M1 (CIT 17/1340), left lower jaw fragment P4, M2-M3 (CIT 17/1339), upper molar UCMP 41081 loc. 4825, lower molar UCMP 41081 loc. 4825, lower molar young adult UCMP 2182, upper molar, little worn UCMP 2182. Mandibles from CIT collection have been illustrated by Stirton (1935).

The material from UCMP collection previously unpublished is illustrated diagramatically in figure 6. The characters of the little worn teeth are those of *D. stirtoni*, with all striids appearing, compare figure 6 A-C with *D. stirtoni* (fig. 4, 5). The lower P4 is like that of *D. stirtoni*.

In combination with the characters of the other known teeth from the Rattlesnake, it seems best to refer this material to *D. stirtoni*.

DIPOIDES cf. D. STIRTONI Wilson

Two specimens from the Thousand Creek formation, a lower P4 and M1, UC 12536, loc. 1103, are apparently all that represents *Dipoides* in the fauna. These specimens have some historical interest as they are the first *Dipoides* material recognized in North America although not the first collected. These specimens have been considered by several authors, especially Kellogg (1910), Wilson (1934), and Stirton (1935).

The P4 exhibits full-length parastriid and a laterally curved tooth column. These are comparable to specimens of *D. stirtoni*. The lower molar has transverse lophs with anterior loph nearly the same size as posterior. This is also characteristic of *D. stirtoni;* the size is closer to *D. smithi*. The material is here referred to *D. stirtoni*.

DIPOIDES REXROADENSIS Hibbard

Dipoides rexroadensis HIBBARD, 1949, Geol. Soc. America Bull., vol. 60, pp. 829–860.

The type is a single upper molar with a simple "S" pattern, from Rexroad fauna, Blancan age. This beaver is much larger than any other known *Dipoides* and stands curiously outside the limits of the other species, It belongs, perhaps, to a new and as yet unnamed genus.

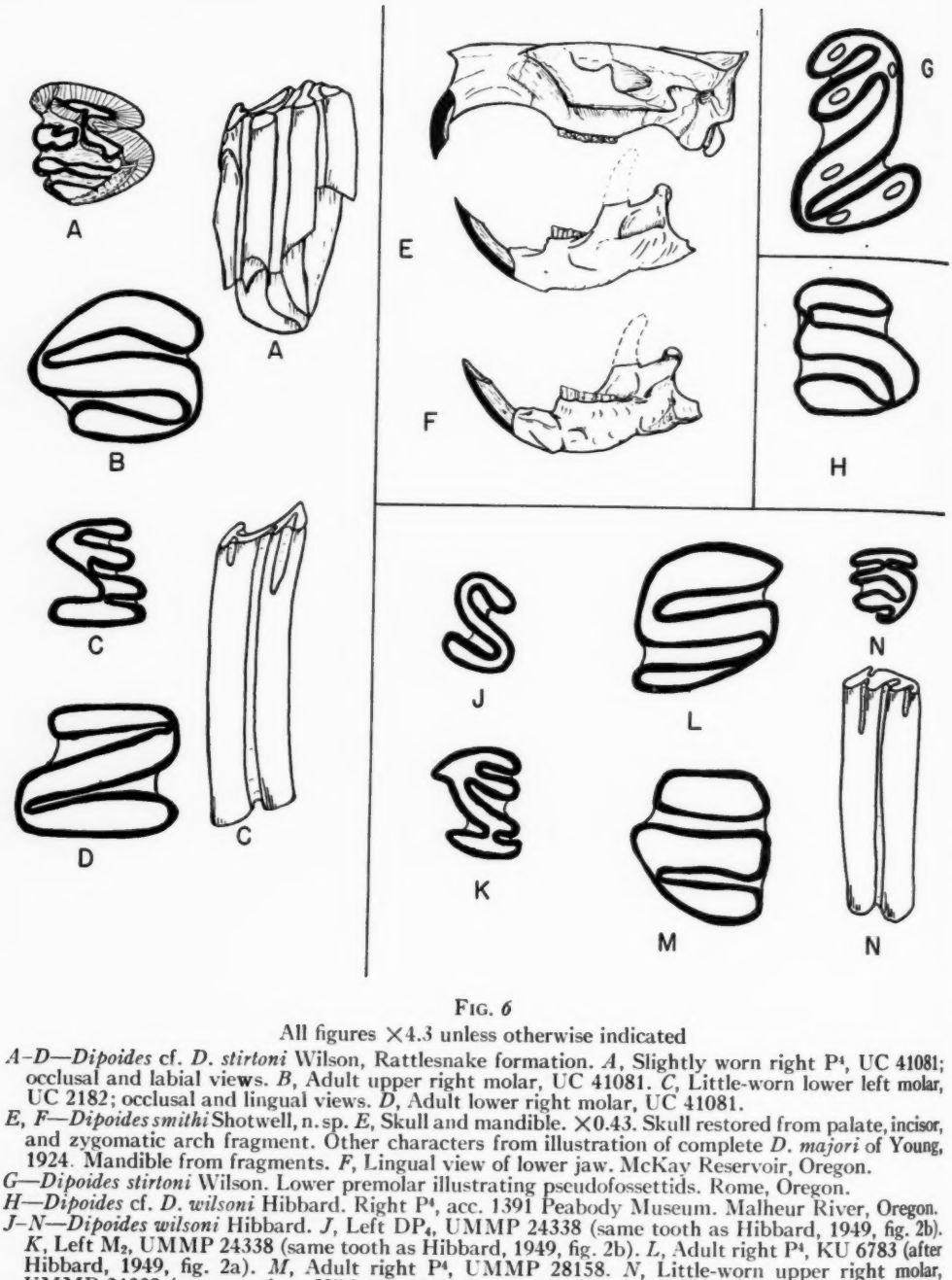

FIG. 6

All figures ×4.3 unless otherwise indicated

A–D—Dipoides cf. *D. stirtoni* Wilson, Rattlesnake formation. *A*, Slightly worn right P^4, UC 41081; occlusal and labial views. *B*, Adult upper right molar, UC 41081. *C*, Little-worn lower left molar, UC 2182; occlusal and lingual views. *D*, Adult lower right molar, UC 41081.

E, F—Dipoides smithi Shotwell, n. sp. *E*, Skull and mandible. ×0.43. Skull restored from palate, incisor, and zygomatic arch fragment. Other characters from illustration of complete *D. majori* of Young, 1924. Mandible from fragments. *F*, Lingual view of lower jaw. McKay Reservoir, Oregon.

G—Dipoides stirtoni Wilson. Lower premolar illustrating pseudofossettids. Rome, Oregon.

H—Dipoides cf. *D. wilsoni* Hibbard. Right P^4, acc. 1391 Peabody Museum. Malheur River, Oregon.

J–N—Dipoides wilsoni Hibbard. *J*, Left DP_4, UMMP 24338 (same tooth as Hibbard, 1949, fig. 2b). *K*, Left M_2, UMMP 24338 (same tooth as Hibbard, 1949, fig. 2b). *L*, Adult right P^4, KU 6783 (after Hibbard, 1949, fig. 2a). *M*, Adult right P^4, UMMP 28158. *N*, Little-worn upper right molar, UMMP 24338 (same tooth as Hibbard, 1949, fig. 2f). Saw Rock Canyon, Kansas.

DIPOIDES WILSONI Hibbard
Text-figure 6 J-N

Dipoides wilsoni HIBBARD, 1949, Contr. Mus. Paleontology Univ. Michigan, vol. 7, no. 5, p. 100.

This is a small species with high-crowned teeth (see table 1) described from the XI member, Saw Rock Canyon formation, "early Blancan or late Hemphillian" (Hibbard, 1949).

Upper dentition. P4 has variations 1 and 4 as discussed below and shown in table 2 and figure 6. Frequency of these variations is not yet known as material seen did not consist of the entire sample collected. The type displays variational as described under variation in characters. Anterior loph rather lenticular. Median loph rectangular and slightly crescentic. Posterior loph pendulous. Flexi nearly transverse; mesoflexus abuts against the enamel, hypoflexus does not.

M1 and M2: Parastria and metastria present in little worn teeth (fig. 6 N), adults, "S" pattern. Flexi transverse and abut against enamel. Lophs shaped much as in premolars.

M3 varies from other molars in hypoflexus being crescentic and median loph and mesoflexus being chevrons. Posterior loph recurves, giving a hook-like appearance as in *D. smithi*.

Lower dentition. P4: The data for the characters of the material seen for *D. wilsoni* appear in tables 1 and 3. Although there are too few specimens available at present it does appear that this species is characterized by a not very persistent parastriid. A moderating influence is the fact that material from Grant County, Oregon, Malheur River, evidently referable to this species, shows about half the P4's with complete parastriids and the other half without parastriids, suggesting a more persistent parastriid.

Molars display parastriids and metastriids in little worn materials. Labial edge of protoconid sharp in little worn specimens. This is characteristic of most species of *Dipoides* (see fig. 6 K). Flexids of adult teeth abutting, with flattened ends. Median loph rectangular. Posterior loph nearly ovoid. Compares with *D. williamsi* in hypsodonty but shape of lophs, flexids and character of upper molars different (see table 1).

DIPOIDES cf. D. WILSONI Hibbard
Text-figure 6 H

A number of specimens of *Dipoides* collected by L. S. Davis and Warfield from along the Malheur River in Grant County, Oregon, compare closely to *D. wilsoni*. These specimens are catalogued as Acc. 1391 in the Peabody Museum. They were collected in the middle of August, 1880. Stratigraphic data on this material are lacking. There also is evidenced some mixing of faunas by the inclusion of oreodont, *Merychippus*, and *Castor* tooth fragments in the collection. The material appears to be picked up as float since it is almost entirely individual teeth or bone fragments. Re-collection in this area is necessary. The *Dipoides* material is considered here to be all of the same species. The material consists of seven lower premolars, six upper premolars, 41 molars and seven incisor fragments.

Upper P4's possess variations 1 and 4 as in *D. wilsoni* but with addition of variation 2, consisting of both a presence of parastria with no paraflexus ("S" pattern) and presence of parastria and a very small paraflexus (see section on occlusal pattern variation for description of these variations). The paraflexus when present meets the bottom edge of the hypoflexus which has a broad end. There is a separating isthmus. (See fig. 6 H.)

Upper molars 1 and 2 as in *D. wilsoni*.

Lower P4's: Some lateral and longitudinal curvature of tooth column. Parastria present about half the time (table 3) illustrating a more persistent parastriid than in *D. smithi* and less than *D. stirtoni*. The relationships of P4 to *D. wilsoni* have been discussed above.

Lower molars as in *D. wilsoni*.

Size of specimens is comparable to that of *D. wilsoni*; also the hypsodonty. Distal ends of flexids squared off as in *D. wilsoni*.

DIPOIDES cf. D. WILSONI Hibbard

Dipoides sp. STIRTON, 1935, Univ. Calif. Pub. Geol. Sci., vol. 23, no. 13, pp. 444.

Stirton illustrates a mandible fragment with premolar, no. 371 HJC in the H. J. Cook collection from the Upper Snake Creek formation. The premolar does not have a parastriid. PA 4.0 mm., TR 4.0 mm. The

size and pattern of the tooth are close to that of *D. wilsoni*. The shape of the lophs in illustration is that of this species.

DIPOIDES sp.

A number of other specimens of *Dipoides* are known from North American deposits. These consist for the most part of single molars, incisor fragments, etc., which can be only tentatively assigned to specific position. There seems little value in guessing what these might be from illustrations.

Eurasian *Dipoides*

D. PROBLEMATICUS Schlosser

This is the type species of the genus. The holotype is a P4. Schlosser (1903) illustrated four upper P4's, all variation 3 of this study. Figure 21a, 23, 23a of Schlosser illustrates two teeth in the position of P4 and M1. These are both apparently P4's. The tooth shown as M1 has full length parastria and metastria with reduced anterior loph. This is characteristic of the upper P4 in *Dipoides* in all material seen. The protocone is angular and tooth is short, probably indicating a young individual. Lower P4 has full length parastriid. The size of the species seems close to the North American *D. wilsoni*, but characters of dentition appear to be as in *D. stirtoni*. These characters are persistent metastria in adults, overlapping of paraflexus by hypoflexus in P4 crescentic shape of median loph of the P4. Rounded face P4, squared-off ends on median loph crescent nearly opposite transversely. It should be emphasized that these remarks are based on illustrations and that, had the specimens been available for study, a different characterization might have been made. Characters that are likely to be reliable in drawings (shapes of lophs excepted) have been used as much as possible.

D. SIGMODUS Gervais, 1845

A large species possibly larger than any North American form. Gervais gives a P4-M3 of 27 mm. The longest tooth row in *D. stirtoni* as given by Wilson (1934) is 22 mm. Illustrations of Gervais show two lower jaws. The P4 of one has a parafossettid, the other a parastriid. It is not possible to tell from the illustrations if the parastriid is complete or not. The molars show open flexids and equal anterior and posterior lophs. Material illustrated as upper dentition (fig. 10 and 10a by Gervais) are not of *Dipoides* but probably of some species of *Chalicomys*. From these illustrations it would seem that *D. sigmodus* represents a species with less persistent parastriid than *D. stirtoni* but more than *D. wilsoni*.

D. MAJORI Schlosser

A large species comparable in size to the North American *D. stirtoni*. Upper premolars exhibit variations 3 and 4 (see section on teeth character variation). Lower P4's apparently have complete parastriid in some specimens while it is absent in others. From measurements it appears *D. majori* may be slightly higher crowned than *D. stirtoni* and less than *D. wilsoni*. This, however, is only suggestive since the method used in measuring the material is not known. A tooth figured by Schlosser (1924, fig. 29a) may be a lower DP4. Schlosser described a small "fresh" tooth but no connection was made with his figure. This tooth displays an "S" pattern. This is characteristic of milk teeth of later *Dipoides*.

VARIATIONS OF DENTAL PATTERN IN *Dipoides*

The cusps as designated by Stirton fit unworn specimens of this genus well. (See figs. 3, 4.) These cusps may be determined in worn material under certain conditions of preservation. In *D. stirtoni* material from the Rome fauna, a staining of what is apparently the boundary between primary and secondary deposition of dentine results in small colored oval rings on the occusal surface. These might, unless carefully examined, be mistaken for true fossettes or fossettids; but they are not surrounded by enamel. They are termed here *pseudofossettes* and *pseudofossettids*. In examining longitudinal sections, pseudofossettes or pseudofossettids are seen to represent the position of pulp cavities and may thus be considered as the position of cusps in unworn teeth. A comparison of figure 6G, which shows a premolar with such pseudofossettids, with figure 4 will demonstrate that this may be a useful characteristic in determining the position of cusps in worn teeth under certain conditions of preservation.

OCCLUSAL PATTERN VARIATIONS

Stirton (1935, 1947) has shown the relative lengthening of striids and striae to be a progressive character in the succession of beavers, *Monosaulax-Eucastor-Dipoides*. *Monosaulax* has short hypo- and mesostriae and striids, disappearing early in wear. *Eucastor* has much more persistent hypostriae, striids and mesostriae and striids, lasting into late wear of adults. *Dipoides* has hypostria hypostriid and mesostria and mesostriid the full length of the tooth. There is also a progression in other striids and striae of these beavers, such as para- and metastriae, striids, but this is not so clear cut, having a wide variation even within species. The relative persistence of these later striae and striids between species and within species of *Dipoides* causes a possible confusion in the relationships of variation in the occlusal pattern which is directly affected by their presence or absence.

In all the unworn teeth of *Dipoides* seen the complete set of striids or striae (para-, meso-, meta- and hypo-) are present. An exception might be found in *D. smithi* which displays only a metafossettid in the lower unworn molars instead of a metastriid.

Upper fourth premolar.—Variations in the occlusal pattern of the upper premolar are largely dependent on the persistence of the parastria, length of hypoflexus and paraflexus and whether the flexi join or are separated by an enamel isthmus. Variations of P4 pattern may be generally divided into four categories:

Variation 1: Parastria and metastria not persistent into the adult tooth. Thus the occlusal pattern is a simple "S." See figures 6L, 3C.

Variation 2: Parastria persistent into adult and probably full length. Paraflexus very small or wanting, hypoflexus clear across tooth with enamel isthmus on labial side. Occlusal pattern "S" results with a prominent notch at site of parastria. See figure 6H.

Variation 3: Parastria persistent into adult teeth and probably full length. Paraflexus present, sometimes nearly half the width of the tooth. Enamel isthmus separates paraflexus from hypoflexus. Hypoflexus deeper than paraflexus, may bypass each other or meet squarely. Metastria may persist into this pattern, sometimes full length. See figures 4L, M.

Variation 4: Parastria persistent into adult teeth and probably full length. Paraflexus and hypoflexus join isolating anterior fold. See figures 4K, 6M.

TABLE 1.—VARIATION IN CHARACTERS IN *Dipoides*

x = this variant is known for the species but the frequency is not established.

A. Upper Premolars

	Variations				Total
	1	2	3	4	
D. stirtoni	0	0	12	1	13
D. smithi	5	0	0	0	5
D. wilsoni	2	0	0	2	4
D. cf. *D. wilsoni*	1	3	0	3	7
D. majori		x	x		
D. problematicus			x		

B. Lower Premolars

	Full parastriid	Incomplete parastriid	No parastriid
D. stirtoni	32	1	0
D. smithi	1	2	16
D. cf. *D. wilsoni*	4	0	3
D. williamsi	0	0	1
D. majori	x		x
D. wilsoni		x	x
D. sigmodus	x	x	
D. problematicus	x		

These may be modified by persistency of the metastria which is generally much shorter than the parastria. The distribution of these variations of striae and striids is indicated in table 1A.

D. smithi and *D. stirtoni* are seen to differ in the frequency of occurrence of their variations. *D. smithi* material displays all variation 1 while *D. stirtoni* shows variations 3 and 4. *D. wilsoni* shows more variations with variation 1 and 4 known from the topotypes and types. Variations 1, 2 and 3 are known from the referred materials. It seems likely that in large samples some specimens of all these variations might be expected.

First and second molars.—These teeth

have much the same variations which are found in the upper premolars. They are not persistent into the adult teeth but do appear in the young adults. The adult pattern is the simple "S." Variations that appear in unworn to young adult teeth are numbers 2 and 3. See figures 4F, 3A.

Upper third molar.—Upper M3 is usually characterized by being very short. The posterior fold varies from an inverted chevron to a completely isolated enamel tube. See figure 3G, H. A new stria and flexus, the medistria and mediflexus, are introduced when the posterior loph isolates.

Lower fourth premolar.—In the lower premolars there are differences between species in the relative length of the parastriid and persistency of the metastriid or metafossettid. These differences are not clear cut and must be considered as variation in frequency of occurrence of characters rather than a quantitative value of length or absence or presence of a character. This is partly due to the unknown total length of ever-growing teeth which does not allow definite lengths of striids to be determined. A comparison of the frequency of adult teeth with complete striids against those in which the striid is worn away or incomplete within faunas, may be a useful method of determining approximate relative length of striids between species. This requires that samples as near random as possible in fossil materials be available. The distribution of striid occurrence is presented in table 1B.

The distribution of frequency of parastriid occurrence in the various species shows *D. stirtoni* to have the highest incidence or, as interpreted here, the most persistent parastriid. *D. smithi* is at the other extreme and *D.* cf. *D. wilsoni* about halfway between.

Lower molars.—Lower molars of *Dipoides* as unworn or little worn teeth have parastriid, metastriid or metafossettid present in all species for which such material was available. See figures 6C, K, 3D, E, 5A, B. The shape of the tooth varies in the course of wear. This may be seen in figures 5A-D and 3D-F. The posterior-anterior measurement is greater than the transverse in little worn teeth but is less than the transverse in adult teeth. This is due to the relative greater broadening of the tooth in early growth. In the little worn and young adult teeth the sides are convergent towards the occlusal surface. In the adults the teeth are prismatic.

VARIATION IN SIZE AND HEIGHT OF CROWN OF *Dipoides*

Among the materials available there were three samples considered large enough to make a study of size and height of crown and which evidently were the complete col-

TABLE 2.—VARIATION IN SIZE IN *Dipoides*

PA—Posterior-anterior measurement
L.—Length of tooth column
S.D.—Standard deviation
TR—Transverse measurement
No.—Number of specimens
Hyps.—Hypsodonty
(measurements in millimeters)

	Mean PA	No.	S.D.	Mean TR	No.	S.D.	Mean L	No.	S.D.	Mean Hyps.	No.	Range
P_4												
D. stirtoni	6.4	19	0.3	4.3	19	0.2	16.4	15	1.6	15.6	17	12.6 18.7
D. smithi	6.0	19	0.3	4.2	19	0.2	15.5	13	1.6	15.7	12	12.7 18.8
D. cf. *D. wilsoni*	4.7	7	0.3	3.5	7	0.2	12.7	7	1.2	19.5	7	17.1 21.3
P^4												
D. stirtoni	4.7	5	0.3	5.5	5	0.1	16.8	5	0.7	16.6	5	13.5 19.0
D. smithi	4.4	5	0.1	5.0	5	0.2	14.5	4	1.7	16.5	4	14.2 17.9
D. cf. *D. wilsoni*	3.5	7	0.2	4.1	7	1.1	12.2	6	0.5	21.2	6	19.9 22.5
Small samples												
P_4												
D. wilsoni	4.8	2		3.9	2							
D. williamsi	5.3	1		3.4	1		14.3+			18.3+		
Rattlesnake specimen	6.4	1		4.6	1							
Thousand Cr. specimen	5.9	1		4.2	1		14.4			14.5		
P^4												
Rattlesnake specimen	4.3	1		5.5	1		17.4					

TABLE 3.—LITTLE-WORN TEETH IN *Dipoides*

L. col.—Length of tooth column
Para —Parastriid or parastriia
Meta —Metastriid or metastria
Full —Stria or striid full length of tooth column
Fos. —Fossette or fossettid only evidence of stria or striid
* —Stria or striid too short to measure
(measurements in millimeters)

	P_4			LM			P^4			LM		
	P. col.	Para	Meta	L. col.	Para	Meta	L. col.	Para	Meta	L. col.	Para	Meta
D. stirtoni	6.1	Full	4.1	8.7	Fos.	0.4	7.4	Full	1.6	9.0	1.6	Fos.
	14.9	Full	Fos.	9.2	3.4	1.4				11.3	*	1.0
D. smithi	12.5	10.2	*	6.7	2.4	Notch				8.9	1.5	Very Short
	6.8	Full	4.8	8.3	2.6	Fos.				8.4	3.1	1.1
				11.5	1.5	*				8.7	4.3	0.6
D. wilsoni										7.5	1.8	0.4
Rattlesnake specimen				10.4	1.5	0.6						

lection of materials from a given locality. These were the California Institute of Technology collection of *D. stirtoni* from Rome, Oregon, the *D. smithi* material described above from McKay Reservoir, Oregon, and the collection of Peabody Museum from the Malheur River, Oregon, referred to *D. wilsoni*. These materials have been examined as to variation in PA, TR, and height of crown. P4's were used exclusively. Molars were not used due to the difficulty in separating M1 and M2's, thus giving additional variation. Height of crown being relative, it was necessary to weigh length of teeth to a standard size occlusal surface to make comparisons. As a standard, a PA of 5 mm. and TR of 5 mm. was used. Results of these measurements appear in table 2. The most striking aspect of this is the relatively equal height of crown of *D. stirtoni* and *D. smithi*, their similar size, the smaller size of *D.* cf. *D. wilsoni* and its greater relative height of crown.

The results suggest a greater similarity between *D. stirtoni* and *D. smithi* than the frequency of striid and stria characters showed in the analysis of occlusal pattern. It would seem that *D. stirtoni* and *D. smithi* are on similar levels of progression in height of crown and size but are diversified in striid characters of the dentition. Their supposed relationship stratigraphically supports this. No stratigraphic data accompany the *D.* cf. *D. wilsoni* material, but the type material of *D. wilsoni* from Saw Rock Canyon, Kansas, is dated near the Hemphillian-Blancan boundary. This adds to a picture of progressive hypsodonty in the phylogeny of *Dipoides*.

Incomplete samples or single specimens have been listed in the lower section of table 2. Their measurements may be compared with those of the complete samples above and some indication gained of their position in relation to the forms used. *D. williamsi* would by this method appear as a late Hemphillian or early Blancan form. Date of the beds in which *D. williamsi* is found is based on the presence of *Dipoides* so that no stratigraphic control is evident. If, however, these beds are found by later evidence to be earlier than late Hemphillian or Blancan there would be reason to conclude that there existed a contemporaneous diversity in hypsodonty among the North American Pliocene beavers.

VARIATIONS IN LITTLE WORN TEETH

As was stated in the section on variation of occlusal pattern the little worn teeth display the full complement of striids and striae or their fossette-fossettid equivalent. Table 3 shows measurements and occurrences of striae, striids, fossettes and fossettids in available little-worn material.

Although this type of material is limited in amount it is valuable in the relationships it may show between characters not apparent in adult teeth and thus not usually available in limited locality material. It may be

seen from table 3 that in lower P4's of *D. smithi* and *D. stirtoni* the metastriid is about 4–5 mm. long while parastriid, hypostriid and mesostriid are full length. Lower molars show the metastriid to be about 2 mm. shorter than parastriid, parastriid being about 3.4 mm. long in *D. stirtoni*. In *D. smithi*, parastriid is not so long, being 2.6 mm. in the longest specimen and about 2.5 mm. longer than metastriid. One specimen of *D. stirtoni* displays a parafossettid before the disappearance of the metastriid. This is evidently due to unusually early closure at the paraflexid. Upper P4 of *D. stirtoni* has 1.6 mm. metastria with complete parastria. Some adult material exhibits a complete metastria. More material for upper molars is available. The table shows parastria to be consistently longer in all specimens. Metastria, when state of wear is considered, vary from 1.5 to about 4 mm. shorter.

Little worn specimens may be easily mistaken for small species of *Eucastor*. This is an important consideration due to the current usage of these genera as index forms in the recognition of North American provincial ages. Young specimens of *Dipoides* may be separated from small adult *Eucastor* specimens as follows: in young *Dipoides* the dentine is only a thin sheet inside the tooth and not solid, molars have a greater PA than TR measurement, and PA is less at top than bottom. In young complete lower dentitions DP4 will still be present, and displays the rabbit pattern in some species; it is two-rooted with short striids. *Eucastor* molars are usually more round in cross-section and the difference in size between P4 and molars is greater than in *Dipoides* in both upper and lower dentitions.

CHARACTERS OF THE DP_4

DP_4's are known for *D. stirtoni*, *D. smithi*, *D. wilsoni* and *?D. majori*. DP_4 of *D. stirtoni* and *D. smithi* have the rabbit pattern. (See fig. 2A.) Striids are short but flexids wear to fossettids which do not disappear with wear. DP_4 of *D. wilsoni* represents a simple "S" pattern (fig. 6J). *D. majori* is similar if the specimen illustrated by Schlosser (1903) is a DP_4. This variation is that of the progression in adult P4's from *Eucastor* to *Dipoides*. It may then be indicative of advancement within *Dipoides* for the DP_4 to display the "S" pattern. The picture of advancement as displayed by DP_4's agrees with the increase in hypsodonty shown in adults of the same species.

DIAGNOSIS OF THE GENUS *Dipoides*

Teeth prismatic with complete hypostria, hypostriid and mesostria, mesostriid. Parastria and parastriid commonly persist into adult premolars often extending the full length of the tooth. Metastria and metastriid shorter than parastria, parastriid in all teeth. Parastria, when present, opposite hypostria. Metastriid, when present, opposite the hypostriid. Hypostriid or hypostria never opposite the mesostriid or mesostria. Fossettes and fossettids present in young individuals but not in adults. Incisor with a convex face. Lower incisor lingual to P4-M2, crossing tooth row to labial side under the M3, ends in a large capsule on lateral side of the ascending ramus. Height of crown of lower P4 between two and three times the PA measurement. Teeth rootless except for closure of pulp cavities in old individuals. This closure occurs earlier in primitive species. Size about that of *Eucastor*. Premolars very nearly the same size as molars. Greater difference in size in uppers than lowers.

Discussion.—Stirton (1935) presented a diagnosis of the genus *Dipoides*. Material known then was very limited. What appears to be a mis-association of specimens by Schlosser (1924) led Stirton to describe the upper molars as also displaying two labial striae. Schlosser figured two teeth as P^4-M^1 which evidently are two P4's. This has been discussed above. There is no material known at present which can be identified with certainty as an upper molar that displays two labial striae in adult specimens. A study of young individuals has shown that there are a number of striae and striids and fossettes and fossettids present early in life which disappear with wear. It has been necessary to modify Stirton's diagnosis in these instances. It is felt that this will help to clarify what *Dipoides* is and without altering the previous concept of its generic identity.

ORIGIN OF *Dipoides*

Dipoides appears to have originated from a stock of *Eucastor* with long hypo- and

metastriae and striids with parastria and parastriid nearly as long or equal to meso- and hypostria and striids, metastria and striid shorter than parastria and striid.

Eucastor sp. from the Truckee local fauna and *Eucastor* sp. from the Brady Pocket local fauna are closest to such a diagnosis. The parastria of upper P4's is not always longer than the metastria but the parafossette persists after the metastria is gone. One of the characters of many *Dipoides* is the opening of parafossettes to a full length parastria while in others the parastria and parafossette are much less persistent and do not appear past young adult stage of wear. Development in both directions in this character within *Dipoides* is indicated therefore. Neither of the above species of *Eucastor* appears to be a direct ancestral form.

Dipoides stocks experienced a diversification into a number of large genera soon after the end of the Hemphillian. These include *Paradipoides*, *Procastoroides* and eventually *Castoroides*. *Castoroides* may be more directly derived from species of *Procastoroides*. These forms in general show no increase in relative height of crown over *Dipoides* species and are for the most part relatively lower crowned than advanced *Dipoides* (*D. wilsoni*). Some structural change is notable in the teeth of *Paradipoides*, for it has an additional anterior fossettid in young individuals. This is evidently a minor character not appearing in adult specimens but indicates some evolution in tooth structure. For the most part relative growth appears to be the important change in the post-Hemphillian beavers.

DISCUSSION

It appears from the material presented here that interspecific and intraspecific variation in *Dipoides* is of two general kinds. One may be designated as horizontal variation which includes local variations within a species and geographical diversification between species at a given time. The other is vertical, and includes characters which are of use in determining phylogenetic relationships and origins. The relegation of variations to one or the other of these types is largely based on the results obtained from a study of populations of *D. stirtoni*, *D. smithi* and *D.* cf. *D. wilsoni*. These special groups were used because of completeness of collections. Characters which are considered indicative of horizontal diversification within *Dipoides* are persistence of parastriids, parastriae, metastriae and metastriids. These characters show variation within species and between the species which are apparently contemporary (*D. stirtoni-D. smithi*). They appear also to be independent to their probable superpositional occurrence in the strata. Thus *D. wilsoni* which occurs later than *D. stirtoni* has less persistent parastriids than *D. stirtoni* but more persistent than *D. smithi* which occurs at nearly the same stratigraphic level as *D. stirtoni*. Characters of phylogenetic or vertical significance are relative height of crown and characters of DP_4. High-crowned species appear in late Hemphillian or early Blancan while lower-crowned forms are found in earlier Hemphillian assemblages. Later forms display an "S"-pattern DP_4 without fossettids while earlier forms have a "rabbit"-pattern DP_4.

European *Dipoides* are most like North American earlier *Dipoides* in characteristics of the adult teeth. Asiatic species evidently have the "S"-pattern DP_4 suggesting closer affinities to latter *Dipoides*. Just when "S" DP_4 appears is not known at present but it is present by early Blancan time.

Identification of material referable to *Dipoides* is sometimes difficult. Similarity in adult patterns makes specific identification tenuous. The separation of M1 and M2 is usually uncertain. M3's usually vary in all their characters so much that specific identifications may be useless. The P4's are probably the most useful in placing specimens in one of the several groups of *Dipoides* Variation in size and relative heights of crown in these groups may be estimated by use of figures determined for the species used above. Character of the DP_4 is also useful. Once the general group is determined some supplementary characters are useful in making a specific identification. These are shape of the end of the flexids and flexi, shape of the lophs, relative size of lophs and persistence of parastriids and parastriae. These are described for each species above.

A cursory examination of the remarks made on dentition variations should caution the separation out of single specimens

as representing new species. Even if such a thing is advisable, typifying the separation would be nearly impossible. Fortunately remains of *Dipoides* usually are a large part of rodent faunas when they do occur and good samples are thus often obtainable.

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NEW SNAKES AND LIZARDS FROM THE EOCENE OF CALIFORNIA

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ABSTRACT—No Eocene snakes or lizards have heretofore been found in North America west of the Rocky Mountains. Two new lizards and one new snake are herein described from Eocene deposits in California: a varanid lizard, *Saniwa brooksi*, n. sp., from the Poway conglomerate of San Diego County; an anguid lizard, *Peltosaurus macrodon*, n. sp., and a large boa, *Boavus affinis*, n. sp., from the Eocene portion of the Sespe formation in Ventura County, California.

INTRODUCTION

No Eocene snakes and lizards have heretofore been found in North America west of the Rocky Mountains. Therefore, it is of some interest to record herein two new lizards and one new snake from the Eocene part of the Sespe formation and the Eocene Poway conglomerate of California.

These reptiles have been found in collections of Eocene age made by the California Institute of Technology at two localities in the Sespe formation as exposed north of Simi Valley, Ventura County, and one locality in the Poway conglomerate near the Mission San Diego, San Diego County, California. The Sespe quarries are situated on the north flank of the Simi anticline between Alamos Canyon on the west and Tapo Canyon on the east. Two of them, localities 207 and 202, are in the section between Alamos and Brea Canyons; the third, locality 180, 3 miles to the east, is somewhat west of Tapo Canyon. The San Diego occurrence, locality 249, is located in the west bank of the San Diego River approximately ¼ mile northeast of the Mission San Diego.

About 7500 feet of Sespe is present in the Alamos-Brea Canyons section, grading upward without break into the lower Miocene Vaqueros formation, but separated at its base by an erosional interval from the marine middle Eocene Llajas formation. The zone of upper Eocene vertebrates occupies a position about 1600 feet above the contact with the Llajas, and more than 4000 feet below the Vaqueros. Locality 180 in Tapo Canyon is apparently nearly equivalent in stratigraphic position and age to localities 202 and 207.

The Poway conglomerate, over 800 feet in thickness, covers a considerable part of the La Jolla quadrangle. The lizard from the Poway was obtained at locality 249 which is not far above the contact with the underlying marine Rose Canyon shale member of the middle Eocene La Jolla formation. Marine invertebrates from the Poway conglomerate have been correlated with those of the Eocene Tejon. The upper part of the Rose Canyon shale is reported to occupy a position transitional between typical Domengine (marine middle Eocene) and typical Tejon. See Hanna (1926), Stock (1937) and Wilson (1940a) for further information on the stratigraphy and geology.

The vertebrate faunas of the Eocene Sespe and Poway localities have been studied by Stock (1933, 1934, 1937, 1938) and Wilson (1940a–c, 1949a–b). These Californian Eocene localities appear to be definitely post-Bridger and are probably equivalent to the Uinta.

The figures have been drawn by Mrs. Joan Arsenault.

SYSTEMATIC DESCRIPTIONS

Order SAURIA
Family VARANIDAE
Subfamily SANIWINAE
SANIWA BROOKSI Brattstrom, n. sp.
Text-figure 1, C, D

Holotype.—No. 5117, California Institute of Technology, consisting of two articulated midthoracic vertebrae, one separate vertebra, and a small fragment of a vertebra.

Type locality and age.—C.I.T. locality 249, upper Eocene, Poway conglomerate, Cliff

face, north side of Mission Valley, approximately ¼ mile northeast of Mission San Diego, San Diego County, California, collected by F. D. Bode and D. Schart.

Diagnosis.—A *Saniwa* characterized by large size, ventral surface of vertebrae slightly convex transversely and straight longitudinally, neural spine far posterior and curving posteriorly. Two times height of ball of centrum greater than width across ball of centrum. Ventral surface of centrum smooth, flat, and continuous with ball posteriorly and cup anteriorly: that is, there is no ridge surrounding the cup nor does the ball extend below the level of the surface of the centrum.

Description of type.—The type consists of two articulated thoracic vertebrae, one separate thoracic vertebra, and one fragment of a thoracic vertebra, probably representing vertebrae numbers 14 to 17. The vertebra are large, with the ventral surface of the centrum slightly convex transversely and straight longitudinally. The flat area of the ventral surface of the centrum is smooth, flat, and continuous with the ball posteriorly and the cup anteriorly: that is, there is no ridge surrounding the cup, nor does the ball extend below the level of the surface of the centrum. The neural spine extends posterior to the postzygapophyses and is even with the posterior edge of the ball. The anterior and posterior edges of the neural spine curve posteriorly. The ball is wider than high, two times the height of the ball greater than the width across the ball. Zygosphene well developed, but small, low, indented anteriorly, and with the anterdorsal edge sharp. The zygantrum is also well developed. The prezygapophyses are solid and slant dorsally. The postzygapophyses are also solid, the articulating surfaces slant downward. The diapophyses are solid, round, fused with the prezygapophyses, and without a depression in the ventral surface. The cup is a transverse ellipse, not obliquely placed but facing straight forward. The neural spine is present on only one of the vertebrae; on the others it is partly broken. The fragment of a vertebra consists of a cup and the right prezygapophyses. The process of the latter measures 5.6 mm. wide. Measurements of the type material are given below in millimeters.

	A	B	C
Height of vertebra	15.7+	17.8	16.5+
Width of vertebra	11.7	12.0	12.0
Length of vertebra at centrum	14.1	14.1	14.4
Height of neural spine	—	4.8	—
Width across prezygapophyses	18.8	19.4	19.4
Width of prezygapophysis process	5.9	5.4	6.0
Width across postzygapophyses	18.4	17.8+	—
Width of postzygapophysis process	5.3	—	—
Centrum ball height	—	5.0	5.0
Centrum ball width	—	9.0	8.8

Discussion.—*Saniwa brooksi* is most closely related to *S. ensidens* Leidy and *S. paucidens* (Marsh). *S. brooksi* differs from these two species in being larger, in having two times the height of the ball greater than the width of the ball, in the absence of ridges separating the cup ventrally, in having the ventral surface of the centrum even with the ball, in having the neural spine extending posteriorly past the postzygapophyses but even with the posterior extent of the centrum, and in having the neural arch transversely across the postzygapophyses slightly triangular, not straight. In addition to the above, *S. brooksi* differs from *S. paucidens* and *S. crassa* (Marsh) in that the centrum is straight longitudinally rather than concave. From *S. grandis* (Marsh), *S. brooksi* differs in that the zygosphene is not infolded forming shelves. *S. brooksi* differs from *S. agilis* (Marsh) in its large size and in having the neural spine strongly developed. Though the outline of the neural arch posteriorly across the postzygapophyses is slightly indented in *S. brooksi* as in *S. agilis*, the neural spine on *brooksi* extends posteriorly more than in *S. agilis*.

Judging from the size of this and other species of *Saniwa*, *S. brooksi* was probably 5 to 6 feet long.

This is the first record of the genus *Saniwa* west of the Rocky Mountains and the first record of a reptile from the Eocene of the Poway formation of San Diego. The other genera of the Saniwinae include the North American genera *Palaeosaniwa*, *Parasaniwa*, the Mongolian genus *Telmasaurus*, and possibly the Australian *Megalania*. All the genera of this subfamily are extinct.

The species is named for Professor Baylor Brooks, Department of Geology, San Diego State College, who has transferred his enthusiasm for geology and paleontology to many students, this one included.

Family ANGUIDAE

Peltosaurus macrodon Brattstrom, n. sp.
Text-figure 1B

Holotype.—No. 5118, California Institute of Technology, consisting of the anterior end of a right dentary and four dermal head or body plates.

Type locality and age.—C.I.T. locality 180, upper Eocene, Sespe formation, north side of Simi Valley, Ventura County, California, in a small exposure of red beds in a large canyon on the east side of the first canyon west of Tapo Canyon or 2.9 miles N. 39.5° E. of Santa Susana Bench Mark 961.

Diagnosis.—A *Peltosaurus* with the teeth less beveled and much larger (in height and width) than any known species and with the anterior end of the dentary blunt.

Description.—The type consists of the anterior end of a right dentary measuring 11.0 mm. long and 6.0 mm. high with a smooth lateral surface containing two mental foramina. The median surface of the dentary has six teeth and two empty sockets (Fig. 1). The tallest tooth is 4.3 mm. high and 1.5 mm. wide and extends above the top of the dentary by 1.2 mm. The teeth are very wide, tall, rounded on top, and only slightly beveled at their outer edges. There are seven teeth in the space of 10 mm. Below the tooth area on the medial side of the dentary there is a deep groove curving dorsally at the anterior end of the bone. Other measurements are presented in Table 1.

Referred material.—One posterior part of a dentary from C.I.T. locality 207 (also on the north side of Simi Valley) measuring 15.4 mm. long is referred to *Peltosaurus macrodon*. This dentary also has tall, wide, slightly beveled teeth. It is quite worn and

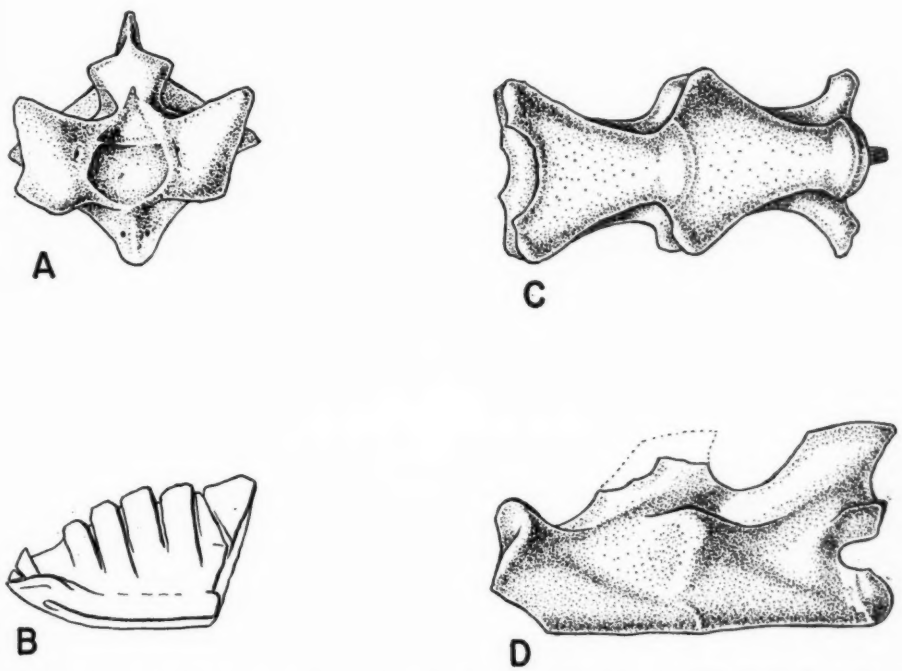

FIG. 1—*A. Boavus affinis* Brattstrom, n. sp., anterior view of holotype, CIT 5119. *B. Peltosaurus macrodon*, Brattstrom, n. sp., medial view of dentary of holotype, CIT 5118. *C, D. Saniwa brooksi* Brattstrom, n. sp., ventral and lateral views of two vertebrae of holotype, CIT 5117. All figures about ×2¼.

TABLE 1.—MEASUREMENTS (IN TENTHS OF MM.) OF DENTARIES OF *Peltosaurus*

Species	Greatest height of dentary	Height tallest tooth	Height tooth above dentary	Number of teeth		Width tallest tooth
				In 10 mm.	In 5 mm.	
P. granulosus (South Dakota)	8 (38–76) 53*	9 (28–39) 33.8	9 (8–14) 10.6	7 (8–9) 8.7	9 (4–4.5) 4.3	9 (8–11) 9.3
P. abbotti (South Dakota)	—	1 (42) 42	2 (12–13) 12.5	2 (10) 10	2 (5) 5	2 (10–11) 11
P. piger (type)	—	26	6	14.3	7	7.7
P. macrodon (type)	60	43	12	7.5	3.5	15
P. macrodon (referred)	74	55	19	6.5	3.2	17

* Number of specimens (range) average.

no outline of the angulare can be seen.

Discussion.—*Peltosaurus macrodon* is the first record of the genus west of the Rocky Mountains. It appears to be most closely related to *P. granulosus* Cope. It differs from the known species, *P. granulosus* Cope, *P. abbotti* Gilmore, and *P. piger* Gilmore in its larger and wider teeth and blunter anterior end of the dentary. *P. macrodon* appears to be intermediate between the Cretaceous (Lance) *P. piger* and *P. abbotti* and *P. granulosus* of the White River Oligocene. Other Cretaceous (Fort Union, Torrejon) and Eocene (Bridger) peltosauri have been too fragmentary for identification (Gilmore, 1928). Measurements of some lower jaws of known species of *Peltosaurus* are presented in Table 1.

Associated with the type dentary there are four dermal plates which appear to be head plates, most likely those just posterior to the parietal. These are considered to be part of the holotype.

Order SERPENTES
Family BOIDAE
Boavus affinis Brattstrom, n. sp.
Text-figure 1A

Holotype.—No. 5119, California Institute of Technology, consisting of one mid-thoracic vertebra.

Type locality and age.—C.I.T. locality 180, upper Eocene, Sespe formation, north side of Simi Valley, Ventura County, California. In a small exposure of red beds in a large canyon on the east side of the first canyon west of Tapo Canyon or 2.9 miles N. 39.5° E. of Santa Susana Bench Mark 961.

Diagnosis.—A large *Boavus* with a massive zygosphene and a strong sub-centrum keel bordered by a depression and a lateral ridge giving a triangular shape to the centrum when viewed ventrally. The sub-centrum keel continuous with the ball, neural canal triangular anteriorly, but slightly depressed, and centrum cup angularly sub-ovate, wider than long. A foramen in a depression in the anterior surface of the prezygapophysis.

Description.—The holotype of *B. affinis* consists of a large mid-thoracic vertebra measuring 17.4 mm. high, 14.7 mm. wide, and 9.7 mm. long at the centrum. The zygosphene is massive, solid, and wider than the cup or centrum. The neural spine is truncate with both anterior and posterior edges slanting posteriorly. The top and posterior edges of the neural spine are the heaviest. The anterior edge of the neural spine starts 1 mm. posterior to the edge of the zygosphene. The cup is angulately sub-ovate, wider than long. The prezygapophysis is massive, solid, and with a foramen on the anterior surface at the edge of the cup. A flat area extends posteriorly from the articulating surface of the prezygapophysis to and continuous with the upper surface of the postzygapophysis. The diapophysis is massive, extending slightly below the cup, smooth, and not divided. A wide, rounded sub-centrum keel is present which expands as it approaches the ball with which it is continuous. Lateral to the keel there is a depression and then a lateral ridge on each side. This gives a triangular shape to the centrum when viewed ventrally. The zygantrum is well developed. The neural canal anteriorly is almost an equilateral triangle; posteriorly it is wider than high.

Referred material.—Three mid-thoracic vertebra from C.I.T. locality 202, upper Eocene, Sespe formation, north side of Simi Valley, Ventura County, California, near the head of the canyon between Brea and Alamos Canyon are referred to *B. affinis*.

These vertebrae agree with the characters of *B. affinis* except that in one of the vertebrae the sub-centrum keel stops before the ball of the centrum, and the zygosphene is more massive and has a median groove at the anterior surface. The rest of the vertebrae agree with the type, but are fragmentary.

Discussion.—*B. affinis* is most closely related to *B. occidentalis* Marsh from which it differs in having a strong sub-centrum keel and in that the keel extends posterior to and is continuous with the ball, the cup of the centrum is wider than long, the neural canal anteriorly is triangular and has a foramen in the anterior surface of the prezygapophysis. There is no ridge anteriorly, extending from the zygopshene to the cup, as in *B. occidentalis*. Besides the above characters, *B. affinis* differs from *B. brevis* Marsh in its larger size and much more massive zygosphene, and from *B. idelmani* Gilmore in its larger size and in having the sub-centrum keel fused to the ball.

This is the first record of the genus *Boavus* outside of Wyoming where the genus has been found in the Bridger (*B. occidentalis*, *B. brevis*), Green River (*B. idelmani*), and Wind River (*B. occidentalis*) Eocene (Gilmore, 1938; White, 1952).

The specific name, *affinis*, was chosen to suggest relationship to the previously described Wyoming species, especially *B. occidentalis*.

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PLIOCENE AND PLEISTOCENE AMPHIBIANS AND REPTILES FROM SOUTHEASTERN ARIZONA

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ABSTRACT—The herpetofaunas of the early Pleistocene Curtis Ranch and late Pliocene Benson and Red Knolls deposits of southeastern Arizona have been examined and include: Red Knolls, *Natrix* sp.; Benson, *Ambystoma tigrinum*, *Bufo* sp., *Crotaphytus* sp., and *Kinosternon arizonense;* Curtis Ranch, *Ambystoma tigrinum*, *Coluber constrictor*, *Lampropeltis intermedius*, n. sp., *Natrix* sp., *Thamnophis* sp., *Crotalus lepidus*, and *Testudo* sp. *Lampropeltis intermedius*, n. sp., and *Kinosternon arizonense* are the only extinct members of the faunas.

The climates of the Benson and Red Knolls localities were probably quite moist. The Curtis Ranch fauna also indicates moist conditions but with some increase in aridity.

INTRODUCTION

FOSSIL vertebrates from the late Pliocene and early Pleistocene deposits of southeastern Arizona are well known. Of these, the Pliocene Benson and the early Pleistocene Curtis Ranch faunas from the San Pedro Valley are the best recorded (Gidley, 1922, 1926; Gazin, 1942). In the nearby Gila Valley, beds of similar vertebrates have been found (Gazin, 1942). These three sites are all probably within the Gila Conglomerate (Knechtel, 1936).

Except for two turtles and a lizard, the herpetofauna of these deposits has been unknown. Examination of material from these sites in the Califronia Institute of Technology and the U. S. National Museum collections, through the courtesy of Mr. William Otto and Dr. C. L. Gazin, has revealed an interesting herpetofauna, including a new species of snake.

The drawings in Figure 2 were made by Mrs. Joan Arsenault.

Location.—Details of the locations, excavation, and history of these sites can be found in the review by Gazin (1942). In brief, the San Pedro Valley localities are known as Benson and Curtis Ranch and are located 2 miles south and 12 miles southeast of Benson, Cochise County, Arizona, respectively. The third site is Red Knolls, near Safford, Gila Valley, Graham County, Arizona (sec. 36, T. 5 S., R. 23 E.).

Faunas.—Gazin (1942) has reviewed the vertebrates of the San Pedro sites. The Benson locality includes *Cordillerion bensonensis*, a mastodont species, *Nannippus*, *Plesippus*, *Platygonus*, *Texoceros* sp., and a camelid. The Curtis Ranch fauna includes *Glyptotherium arizonae*, *Canis edwardii*, *Felis* near *F. lacustris*, *Felis* near *F. atrox* *Stegomastodon arizonae*, *Equus* sp., *Tanupolama*, *Capromeryx gidleyi*, and *Odocoileus*. Other vertebrates of the two sites include bats, rodents, lagomorphs, and fossil birds (Gidley, 1922, 1926; Gazin, 1942; Stirton, 1931, 1936; Wetmore, 1924; Wilson, 1937; Wood, 1935). The Gila Valley locality includes *Nannippus*, *Plesippus*, and glyptodont material (Gazin, 1942).

The herpetofaunas of these three sites are as follows:

Curtis Ranch
- *Ambystoma tigrinum*
- *Coluber constrictor*
- **Lampropeltis intermedius* n. sp.
- *Natrix* sp.
- *Thamnophis* sp.
- *Crotalus lepidus*
- *Testudo* sp.

Benson
- *Ambystoma tigrinum*
- *Bufo* sp.
- *Crotaphytus* sp.
- **Kinosternon arizonense*

Red Knolls
- *Natrix* sp.

* Extinct.

Age.—Though the Curtis Ranch and Benson localities were first thought to be Pliocene (Gidley, 1922), the Benson locality is now considered to be upper Pliocene and the Curtis Ranch very early Pleistocene. The Gila Valley site is probably equivalent to the Benson. See Gazin (1942) and Knechtel (1936) for a further discussion.

Climate.—When paleobotanical evidence is not available, reptiles and amphibians are probably more useful in determining Cenozoic climates than the other vertebrates. Most of the species known from the Arizona sites are living today. Since modern reptiles and amphibians are often restricted to certain life zones, plant communities, etc., we can use them to speculate as to the climates of many Cenozoic deposits.

The Benson locality was obviously fresh water, either a bog, marsh, pool, or small lake. This is supported by the salamander, toad, and mud-turtle; by such birds as ducks, rails, and scolopacids; and by the boggy conditions as evidenced stratigraphically (Gidley, 1926). The Gila valley probably had the same climate.

The Curtis Ranch fauna suggests a slightly drier habitat, but still moist and with some fresh water pools or streams. It was probably surrounded by a grassland and semi-arid transition life zone containing junipers and pines, much as could be found today at higher elevations in the nearby Chiricahua or Huachuca Mountains.

Knechtel (1936) suggests that the climate of the late Pliocene of southeastern Arizona was humid and warm with volcanic activity nearby. As Axelrod (1950) has shown, the present desert regions did not come into existence until after upper Pliocene times. The moist Benson and Gila localities and the less moist Curtis Ranch site may indicate this trend toward increasing aridness.

SYSTEMATIC DESCRIPTIONS

Class AMPHIBIA

Family AMBYSTOMIDAE

AMBYSTOMA TIGRINUM Green

Tiger salamander remains come from both the Benson and Curtis Ranch sites. From Curtis Ranch there is one narrrow atlas vertebra in the California Institute of Technology collection measuring 5.1 mm. in length (at centrum), 6.0 mm. high and 5.1 mm. wide at the anterior condyles. It does not differ from atlas vertebrae of recent *A. tigrinum*. The neural spine is high, squarish, and thick, the anterior and posterior edges are nearly straight and even with the neural canal at both ends. The anterior condyles are double, lateral, and flat for articulation with the cranium. The neural canal is small, roundish and with a ventral projection (a continuation of the floor of the canal) passing anteriorly, dorsal and medial to the two anterior condyles, about 1.3 mm. forward of the condyles. Posteriorly the centrum is hollow (concave). The postzygapophysis descends from the neural spine and extends posteriorly slightly. Ventrally the centrum is roughly triangular with a retangular, flat, posterior process which is the width of, and continuous with, the centrum posteriorly.

The U.S.N.M. material (20670) from Curtis Ranch consists of two thoracic vertebrae which are typical of the species. The centrum length of one of these is 3.9 mm.

From the Benson locality, there is a partly damaged thoracic vertebra and a partly damaged atlas (U.S.N.M. 20673) of this same species. On the atlas, the neural spine and postzygapophyses are broken. It is 5.0 mm. wide at the anterior condyles. It differs from the Curtis Ranch material and recent skeletons only in that the neural canal (when viewed from the front) is higher and is pointed dorsally.

Family BUFONIDAE

BUFO sp.

Most anuran remains are indistinguishable on the specific level on the basis of leg bones and girdles unless unusually different (*i.e.* unless a bone with a particular process or shape is found). Vertebrae are the best means of distinguishing families and sometimes genera of anurans. Taylor (1942) has used the sacral vertebra of anurans for some specific determinations, but most specific identifications of fossil frogs and toads should wait until skull parts are available or some diagnostic bone is evident. Therefore, the anuran material from Benson (U.S.N.M. 20672), which consists of a few fragments of leg bones and an ilium, is referred only to the genus *Bufo*.

Class REPTILIA

Order SERPENTES

Family COLUBRIDAE

COLUBER CONSTRICTOR Linnaeus

Vertebrae of *Coluber* from Curtis Ranch (C. I. T. 8 vertebrae; U.S.N.M. 13687, 3 vertebrae) do not differ from those of Recent *C. constrictor*. The vertebrae are too small

for *Masticophis* and the sub-centrum keel is narrow, thin, and ends anteriorly at the edge of the centrum cup as in *C. constrictor*, not thick, flattened, and ending prior to the cup as in *Masticophis*.

Lampropeltis intermedius
Brattstrom, n. sp.
Text-figures 1 A, 2

Holotype.—No. 5121, California Institute of Technology, a midthoracic vertebra.

Type Locality and age.—Lower Pleistocene, Curtis Ranch, St. David, San Pedro Valley, Cochise County, Arizona.

Diagnosis.—A *Lampropeltis* with a medium sized sub-centrum keel bordered by two rounded ridges which gently slope convergently towards the ball of the centrum. Top of zygosphene slants downward when viewed anteriorly.

Description.—The type consists of a midthoracic vertebra whose measurements are given in Table 1. The vertebra is squarish with a broken neural spine and an upward slanting prezygapophysis with a small process extending lateral to the articulating surface. The postzygapophysis is somewhat flattened and thin at the area of the zygantrum. The top of the zygosphene is slightly tilted or slanted downward when viewed from the front. When viewed from the top the zygosphene has hooks on its anterolateral corners and the front surface is even with the front of the prezygapophyses. The centrum cup is round and the centrum has a sub-centrum keel or ridge which ends at the edge of the cup and just before the ball. Lateral to the keel, especially anteriorly, there are two parallel grooves, bordered by a curved ridge which extends dorsally to form the side of the vertebra. These ridges gently slope convergently towards the ball of the centrum. There are two lateral, partly divided, dumbell-shaped diapophyses for articulation with the ribs.

Referred material.—Other than the type, there are two *Lampropeltis intermedius* veretebrae from the Curtis Ranch locality. This includes C.I.T. 5122 which does not differ from the type except that the left side of the pre- and postzygapophyses are broken. The prezygapophysis is more anteriorly projected and the grooves lateral to the sub-centrum keel are longer. U.S.N.M. 20671, from the same locality does not differ from the type. It is small and badly damaged.

From C.I.T. locality 505, Pliocene, Goleta formation, Morelia, Michoacan, Mexico, collected on the most northern barranca on the west side of the north drainage basin, ¾ mi. S. W. of Colonia Miguel Hidalgo, there is a midthoracic vertebra which does not differ from the type of *L. intermedius* except that it is larger. It is referred to this species and extends the range some 1000 miles to the south. On this vertebra the neural spine is also broken as are the processes of the pre- and postzygapophyses. The arch of the postzygapophysis is slightly rounder than the type. The sub-centrum keel is thin and well developed in this specimen. The measurements of the known material of *L. intermedius* are presented in Table 1.

Discussion.—*L. intermedius* differs from *L. pyromelana* in that the top of the zygosphene slants downward and is not flat across as in *L. pyromelana*. *L. intermedius* agrees with *L. pyromelana* in the shape of the centrum when viewed from below. *L.*

TABLE 1.—MEASUREMENTS (IN TENTHS OF MM.) OF THE KNOWN MATERIAL OF *Lampropeltis intermedius* BRATTSTROM, N.SP.

	Curtis Ranch			Mexico
	Type	CIT	USNM	CIT
Width of vertebra	40	36	29	66
Length of vertebra at centrum	49	47	—	70
Centrum height and width	20–20	20–23	—	33–35
Width across prezygapophyses	84	—	—	108
Width of process of prezygapophysis	15	12	—	28
Width across postzygapophyses	66	—	45	100
Width of process of postzygapophysis	20	—	13	26
Height of zygosphene from top of cup	23	24	14	39
Width across zygosphene	31	—	24	54

intermedius agrees with *L. doliata* in the shape of the zygosphene, but differs in that the centrum ridges (when viewed from below) are narrow as they approach the ball in *L. doliata*. *L. intermedius* differs from *L. getulus* in the shape of the zygosphene and centrum. In *L. getulus* the zygosphene is flat on top, the centrum ridges bulge as they approach the centrum ball, the keel is better developed and the grooves lateral to the keel are longer and deeper than in *L. intermedius*. *L. intermedius* differs from *L. zonata* in the shape of the centrum when viewed from below, which is slightly bulging as it approaches the centrum ball in *L. zonata*, much as in *L. getulus*. *L. zonata* differs from *L. getulus* and *L. intermedius* in having the deepest portion of the grooves lateral to the subcentrum keel in the middle of the vertebra, not anteriorly. *L. zonata* agrees with *L. intermedius* in the shape of the top of the *zygosphene*. The ridges lateral to the subcentrum keel are rounded in *L. intermedius*, *L. doliata*, and *L. pryomelana* and not sharp (giving a flat appearance to the ventral surface) as in *L. getulus* and *L. zonata*. These differences are illustrated in Figure 1.

L. intermedius is most closely related to *L. doliata*, *L. pryomelana*, and *L. zonata*, hence the trivial name, *intermedius*. It is possible that some of the confusion in the origin of these three Recent species (Zweifel, 1952; Tanner, 1953); might be straightened out by considering the extinct, wide-ranging, *L. intermedius* as the stem form for all three of these Recent species.

THAMNOPHIS sp.

The only garter snake material comes from Curtis Ranch (U.S.N.M. 20669) and consists of one elongate vertebra whose centrum length is 5.5 mm.

NATRIX sp.

Water snake and garter snake vertebrae are difficult to distinguish in Recent forms. It therefore, becomes increasingly difficult to determine fossil natricine vertebrae, as they are usually damaged. Tentatively, elongate and usually small natricine vertebrae have been identified as *Thamnophis* and squarish and usually large ones as *Natrix*. On this basis, *Natrix* material comes from Curtis Ranch (U.S.N.M. 20664, 1 vertebra; centrum length 5.3 mm.) and Red Knolls (U.S.N.M. 20663, 2 vertebrae; centrum length of one, 5.5 mm.). All three of these vertebrae are broken and additional material may change some of these determinations from *Natrix* to *Thamnophis*.

Family CROTALIDAE

Crotalus cf. *C. lepidus* (Kennicott)

One small vertebra is probably *C. lepidus* as it agrees with it in all characters, but unfortunately the fossil is so fragmentary that it can only tentatively be referred to this species.

Order SAURIA
Family IGUANIDAE
CROTAPHYTUS sp.

This fossil lizard is known only from one badly damaged left dentary (U.S.N.M. 10690) from the Benson locality. It was first reported by Gilmore (1928, p. 29) and is figured there (Gilmore, 1928, pl. 27, fig. 6). The bone is so fragmentary that anything but generic determination is impossible until more material is available.

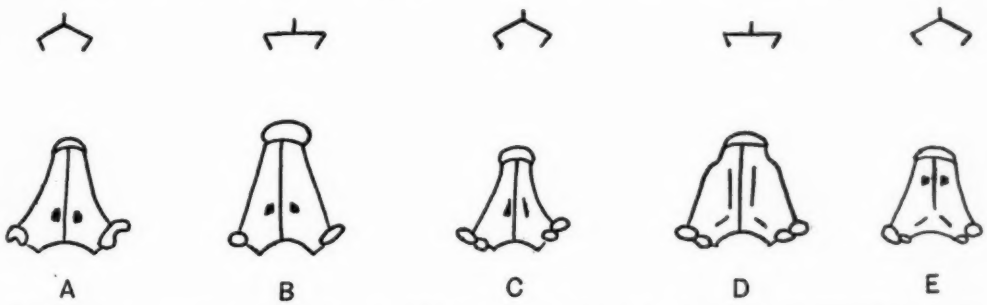

FIG. 1—Diagrammatic ventral view of midthoracic vertebrae and (top) shape of zygosphene when viewed from the front of *A. Lampropeltis intermedius*, *B. L. pyromelana*, *C. L. doliata*, *D. L. getulus*, and *E. L. zonata*.

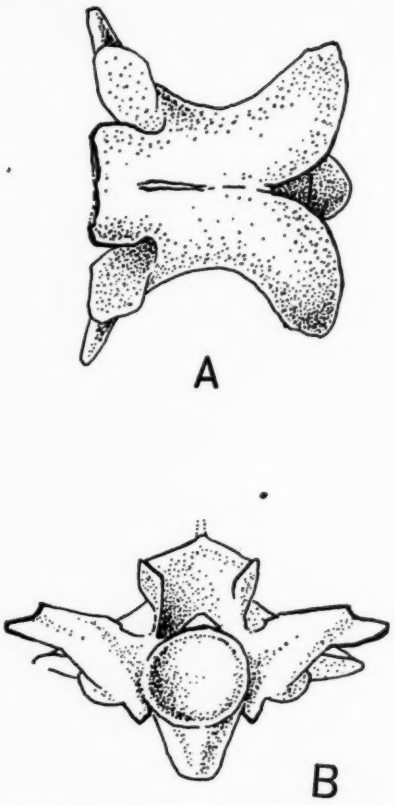

FIG. 2—*Lampropeltis intermedius* Brattstrom, n. sp. Holotype vertebra, C.I.T. 5121. *A*. Dorsal view, *B*. Anterior view. Both approximately ×6.

Order TESTUDINATA
Family TESTUDINIDAE
TESTUDO sp.

Gazin (1942) records the genus *Testudo* from the Curtis Ranch fauna. Considering the area in which the genus evolved, this material probably should be referred to *Gopherus*, although the writer has not seen it.

Family KINOSTERNIDAE
KINOSTERNON ARIZONENSE Gilmore

Gilmore described this extinct species of mud turtle in 1922 from two shells (U.S.N.M. 10463, type; 10462, paratype) from the Benson site. In a jar of anuran remains from this site there were some turtle remains (U.S.N.M. 20665) which are probably of this species. These include several cervical vertebrae and girdle fragments. Since the species is described on the basis of the shell, and since this additional material is probably nondiagnostic, it is just tentatively referred to this species.

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MORPHOLOGY OF *ASTARTELLA*, A PRIMITIVE HETERODONT PELECYPOD[1]

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ABSTRACT—The astartids are considered to be true heterodont pelecypods. The Pennsylvanian and Permian genus *Astartella* is a member of the Astartidae.

Astartella is one of the commonest pelecypods in Pennsylvanian marine shales in the United States. The genus was described by Hall (1858, p. 715) on the basis of a sole species, *Astartella vera*, from the Coal Measures of Illinois and Indiana. The only comment by the author as to the systematic position of the genus was, "Related to *Astarte*." Girty (1927) redescribed *Astartella* in some detail but did not use standard terminology for the hinge area of pelecypods; furthermore, he made no attempt to assign the genus to a family. Shimer and Shrock (1944, p. 417) placed *Astartella* in the superfamily Cypricardiacea, but they gave no reasons for the allocation. Most paleontologists have assigned the genus to the family Astartidae without question or comment.

In the U.S. National Museum there are several lots of excellently preserved specimens of *Astartella* from Pennsylvanian strata in Texas, and this study is based mainly on this material. However, the type species was also examined to be certain that the Texas specimens were congeneric with it.

Form of valves and ornamentation.—The valves are ovate to subquadrate with the beaks strongly prosogyrate and located near the anterior end of the dorsal border. The valves are approximately equal and without gape. Most living astartids are more ovate and, unlike *Astartella*, have little posterior truncation. Furthermore, the living astartids are generally much less obese; the ratio of height to convexity is 0.51 for a typical living astartid species as compared to 0.84 for some Pennyslvanian specimens of *Astartella*. Modern astartids usually have little or no umbonal cavity, but it is well developed in *Astartella*. Like living astartids, *Astartella* has a well developed lunule and escutcheon. The ornamentaion on *Astartella* is similar to that of most living astartids; that is, it consists of well spaced concentric ridges interspaced with many concentric lines. No radial ornamentation was observed on either *Astartella* or modern astartids. *Astartella* has fine crenulations on the anterior, ventral, and posterior inner margins of the shell, and these crenulations look like those on living astartids. An interesting feature of the valves of *Astartella* and of a few living species of astartids is that in the lunular area the right valve slightly overlaps the left, whereas in the escutcheonal area the left valve slightly overlaps the right. In other respects the valves are equal in size.

Muscle scars and pallial line.—The pallial line and adductor muscle scars of *Astartella* are like those of most living astartids. The pallial line is integripalliate and runs from the ventral margin of the anterior adductor muscle scar to the ventral edge of the posterior adductor muscle scar. The adductor muscle scars are almost equal in size, but the anterior one is usually deeper, particularly at its dorsal margin. These scars are located just below the end of the hinge plate in *Astartella*, and they are slightly smaller and located a little more dorsally than those of living astartids. *Astartella* has another typically astartid feature; on the side of the anterior end of the hinge plate and located dorsally and posteriorly to the anterior adductor muscle scar is a small but deep scar that lodged the anterior pedal retractor muscle.

The ligament and nymphae.—Girty (1927, pp. 420–421) described in considerable detail a structure which he thought probably lodged the ligament. The structure he described is what conchologists call a nympha. It is a shelf which extends dorsally from the

[1] Published by permission of the Secretary of the Smithsonian Institution.

hinge plate and is usually located behind the beaks. In each valve the nympha has a chink behind it which separates it from the main portion of the valve, and this chink lodges a small part of the ligament. The main portion of the external alivincular ligament extends up and over the nymphae and completely conceals them while the valves are joined. *Astartella*, like modern astartids, probably had an external alivincular ligament which was opisthodetic and lodged between the nymphae and the main part of the shell.

The hinge teeth.—There are two cardinal teeth in the right valve of *Astartella*, and both teeth are easily seen in well preserved specimens. This observation agrees with that of Hall (1858, p. 715) on the type species. Girty (1927, pp. 418–423) believed that there was only one tooth in each valve; but I have examined a right valve that Girty illustrated, and I have found that there is one large anterior cardinal tooth and one small posterior cardinal tooth. Specimens in the U. S. National Museum collection show the smaller tooth much more clearly. Many living astartids have a small posterior cardinal tooth on the right valve.

On the basis of the hinge teeth, many conchologists and paleontologists have considered the astartids the most primitive of the Heterodonta. The astartids vary greatly in the number and size of cardinal and lateral teeth. This has led some paleontologists to place them with the lucinoid type and others with the cyrenoid type of heterodonts. Davies pointed out (1935, p. 136) that the Astartacea and Carditacea are "deceptive forms." Douvillé (1912, pp. 448–449) and Davies (1935, pp. 155–156) placed the astartids with the lucinoid pelecypods, but Schmidt (1935, p. 50) and Moret (1940, pp. 347–348) allocated them to the cyrenoid pelecypods. Careful examination and detailed comparison of the position and size of the teeth indicate that the hinge of the astartids resembles that of such cyrenoids as *Arctica* and *Chione* rather than that of such lucinoids as *Codakia* and *Fimbria*. However, it is not at all certain that all heterodont pelecypods can be neatly placed into two groups based only on the hinge teeth; and even if a dichotomy were correct, perhaps other morphological characters, such as the ligament, would have to be considered.

Assuming that the astartids have cyrenoid dentition, the anterior cardinal tooth of the right valve is tooth 1. This tooth is relatively slender and slopes inward toward the beak; its most prominent part is near the ventral margin. Tooth 1 is perpendicular to the dorsal margin and begins under the beak and ends at the ventral margin of the hinge plate. Posterior to tooth 1 is a prominent socket of subtriangular shape; the apex of the triangle is dorsal. On the posterior margin of the socket is the small, slender tooth 3b; on worn specimens this tooth is commonly broken off. Tooth 3b begins near the anterior end of the nympha and runs posteriorly and ventrally to a point near the ventral margin of the hinge plate.

There are also two cardinal teeth on the left valve of *Astartella*, but the anterior one is small and the posterior one is large. The anterior tooth, 2a, is located at the anterior end of the hinge plate and is easily broken off or worn away when the valves have been separated. On living astartids it is almost at the anterior end of the hinge plate. Tooth 2a is located under the beak and just behind the lunule; it is perpendicular to the hinge plate and is usually narrow. Behind tooth 2a is a deep socket for the reception of tooth 1 of the right valve. On the other side of the socket is tooth 2b, the largest tooth in either valve. It is a triangular tooth with the apex near the dorsal margin and the base near the ventral margin; tooth 2b runs nearly perpendicular to the hinge plate. Behind tooth 2b is a small, narrow socket for the reception of tooth 3b of the right valve. The formula for the cardinal teeth of *Astartella* is 1,3b/2a,2b. This is similar to the formula Schmidt (1935, p. 50) gave for the hinge of *Astarte*.

The lateral teeth of *Astartella* are like those of most living astartids and some crassatellids such as *Crassinella*, in that the sharp edge of one valve fits into a groove on the other valve. In the right valve of *Astartella* the part of the hinge plate anterior to the cardinal teeth bears a groove; in the left valve anterior to the cardinal teeth is a sharp edge which fits into the groove, so that in the lunular area the right valve actually overlaps the left valve. On the

FIGS. 1–4—Hinge areas of *Astarte* and *Astartella*; n, nymph; 1, 3b, cardinal teeth of right valve; 2a, 2b, cardinal teeth of left valve. *1, 4—Astarte sulcata* (da Costa); Recent, Wales. Hypotype, USNM 200860, ×3.6; *1*, left valve; *4*, right valve. *2, 3—Astartella concentrica* (Conrad); Pennsylvanian, Graford formation; Martin's Lake, 1¼ miles south of Bridgeport, Texas; ×4.8. *2*, right valve; hypotype, USNM 119081; *3*, left valve; hypotype, USNM 119081a.

posterior part of the hinge plate the opposite is true; the left valve bears the groove, and the knife-like edge of the right valve fits into it, so that the left valve overlaps the right one on the escutcheonal area. These structures are so simple that one wonders whether they are true lateral teeth, although they have generally been so considered in modern astartids. If they are lateral teeth, the right valve has two anterior laterals (the groove), and the left valve has but one. The left valve of *Astartella* has two posterior lateral teeth (the groove) and the right valve one. The posterior laterals are at least twice as long as the anterior laterals. The complete hinge formula for *Astartella* is AI, AIII, 1, 3b, PIII/AII, 2a, 2b, PII, PIV. However, *Astartella*, like all astartids, shows variation of the hinge teeth; for example, a left valve of *Astartella varica* McChesney has two anterior lateral teeth as well as two posterior lateral teeth.

CONCLUSIONS

1. On the basis of the morphology of the shell, *Astartella* is a member of the family Astartidae. This genus differs from most living astartids in that it has a greater convexity, it has an umbonal cavity, tooth 2a is at the anterior end of the hinge plate, and the adductor muscle scars are located a little more dorsally and are smaller than those of living astartids. But all of these differences are minor. *Astartella* is like the astartids in the following features: the lunule and escutcheon are well developed; there are crenulations on the anterior, ventral, and posterior inner margins of the valves; concentric ornamentation consists of prominent widely spaced ribs with fine concentric lines in the interspaces; radial ornamentation is absent; the adductor muscle scars, pallial line, and anterior pedal retractor scar of the foot are all similar to those of modern astartids; nymphae are present; and, finally, the number, size, and position of the hinge teeth are typically astartid. Figures 1–4 show the striking similarity of the hinge of *Astartella* to that of a living astartid species.

2. The Astartidae, as represented by *Astartella*, existed at least as early as Pennsylvanian time.

3. If the astartids are heterodont pelecypods with true lateral teeth, this hinge type appeared as early as the Pennsylvanian. This is contrary to what has been written in some textbooks of paleontology; as one example, Swinnerton (1930, p. 266) stated that true lateral teeth did not appear before the early Mesozoic. If the astartids are cyrenoid (and this is more doubtful) rather than lucinoid heterodonts, then the cyrenoids appeared at least as early as Pennsylvanian time.

4. The appearance of *Astartella* in Pennsylvanian time lends support to the phylogenetic ideas of Pelseneer (1911, p. 123) and others who, on the basis of either the ctenidia or the hinge teeth, placed the astartids at or near the base of the highest order of the pelecypods.

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I am particularly indebted to Mr. Lawrence Isham for the drawings of the hinge areas of *Astartella* and *Astarte*. Mr. Mackenzie Gordon, Jr., of the U. S. Geological Survey, located Girty's specimens and gave helpful suggestions on the problem. Mr. Norman Sohl of the University of Illinois, Mr. Charles W. Collinson of the Illinois Geological Survey, and Mr. T. G. Perry of Indiana University kindly loaned me specimens of *Astartella vera*. I am grateful for the assistance from these people.

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EXPERIMENTS ON RELATIVE STREAMLINING OF COILED CEPHALOPOD SHELLS

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ABSTRACT—Flume experiments on 21 specimens of coiled nautiloids and ammonoids were made to obtain quantitative data on their relative streamlining. Involute shells are better streamlined than evolute forms; however, evolute, compressed shells also showed favorable streamlining factors. Widely umbilicate shells with depressed whorl sections have much less favorable streamlining, as also do coarsely ornamented forms. The data substantiate generally held views on the relative streamlining of various types of cephalopod shells.

INTRODUCTION

THAT coiled cephalopods have a wide range of adaptations has long been assumed. The nature of these adaptations and the degree of correlation between conch form and a particular environmental niche has likewise been a fruitful subject of speculation. Data on the habitat and mode of life of *Nautilus*, the only remaining cephalopod genus with a coiled exterior shell, have quite naturally played a very important role in the interpretation of fossils forms. Even with with modern *Nautilus*, however, the observational data are very limited, being principally known through the works of A. Willey (1902) and Bashford Dean (1901). Data on modern *Nautilus* have recently been very ably summarized by Stenzel (1948, 1952). Discussions on the habitat and mode of life of fossil cephalopods have been variously treated by Diener (1912, 1916), Dacqué (1921), Dunbar (1924), Berry (1928), Ruedemann (1921), Scott (1940), Trueman (1941), Schmidt (1930), Spath (1919), Arkell (1949), and many others. The older idea that *Nautilus* is primarily a crawling creature has been completely discredited by Willey and Dean. Likewise, the crawling attitude of Mesozoic ammonites without a hyponomic sinus (Hyatt, 1900, p. 544) is no longer accepted. Hyatt also proposed a thesis that abnormally coiled forms were catagenetic, that is, racially degenerate forms. This interpretation is denied by all modern workers on fossil cephalopods beginning with Diener who interpreted conch form in terms of adaptation. The coiled cephalopod shell is a highly developed hydrostatic apparatus. Recently Trueman (1941) has investigated the various aspects of the ammonite body chamber on terms of volume and density. The observations of Willey and Dean clearly demonstrated that the mean density of living *Nautilus* (air chamber, shell and animal) is the same as that of sea water and Trueman has established that this same relationship held for most ammonites. Those ammonites with a large ratio between the body chamber and air chamber (e.g., *Liparoceras*) probably were heavier than water and thus dwelled on the bottom except when swimming (Trueman, 1941). The heteromorph ammonites also have been shown by Trueman to have had densities about that of sea water and thus could not have been strictly benthonic forms.

The relative streamlining of the cephalopod shell is a factor that has received only brief incidental treatment. Most authors are agreed that oxycones are "efficient" swimmers and that more inflated involute forms had a more nautilan mode of life as relatively poorer swimmers. The stimulus to investigate the relative streamlining of cephalopod shells was obtained a few years ago while talking with Bobb Schaeffer of the American Museum of Natural History on the adaptive significance of shape and mode of locomotion of fossil fish and on experimental studies on models of fish. The present experiments were carried on in the laboratories of the Mechanical Engineering Department of the University of Illinois. We are pleased to acknowledge the enthusiastic help and suggestions of Dr. H. H.

Korst in planning the experimental set-up and the mathematical treatment of the data. A. K. Miller of State University of Iowa kindly loaned specimens of Paleozoic goniatites for the experiments. The conclusions presented here are only of a preliminary nature; however, the data available on 21 miscellaneous cephalopod shells are thought to be of interest.

The results of an experimental approach to a study of the relative streamlining of ammonoid shells were described briefly by Herman Schmidt (1930, p. 198). In his experiments Schmidt used four specimens of approximately the same volume (1500 cc.) and obtained a value for the drag on each of the specimens with the following equation:

$$\text{Drag} = \frac{\text{Resistance in Kg}}{\text{Force per unit area} \times \sqrt[3]{\text{Vol.}^2}}$$

The values of the drag for the species used by Schmidt are:

Ceratites semipartitus	0.22
Macrocephalites	0.39
Crioceras roemeri	0.42
Ceratites nodosus	0.43

From his experiments Schmidt concluded that the compressed, involute shells had the best streamlining and the poorest streamlining is found in widely umbilicate forms, with the depressed involute forms intermediate. Schmidt unfortunately did not describe the apparatus used in his experiments.

Wind tunnel and flume experiments have been performed on models of fish by various zoologists (Breder, 1926; Grove and Newell, 1936, 1939; Harris, 1936, 1937, 1938). A stimulating discussion on the mechanical factors controlling swimming position in aquatic animals has been given by Lockhead (1942).

DESCRIPTION OF EXPERIMENT

The apparatus employed in the experiment consisted of a water table to provide a stream of water the velocity of which could be varied and measured, and a device to determine the drag on a specimen submerged in the stream.

The stream table (Fig. 1) consisted of a pump, two reservoirs (upstream and downstream), a dam to limit the flow of water to a narrow channel and a weir at the downstream end of the channel to control the depth of the stream. In operation the mass flow of the water through the system was varied by means of a valve and measured with a manometer. The depth of water in the channel was kept constant by adjusting the weir. The velocity of the stream was determined by converting the mass flow to volume flow and dividing this figure by the cross-sectional area of the channel at the point where the specimen was submerged.

The drag measuring device (Fig. 2) is a modification of a beam balance. The force exerted on the specimen was counterbalanced by sliding the weight out on the horizontal arm. In operation the specimen was submerged in water of zero velocity, and with the sliding weight at zero, the system balanced by means of the counter-weight. This compensated for differences in specific gravity, and positions of center of gravity and center of buoyancy which varied from specimen to specimen. The water was then allowed to flow. The displacement of the lever system resulting from drag on the specimen was balanced by moving the sliding weight out on the arm. The distance moved is proportional to the force on the specimen.

Plaster casts of 21 species of nautiloids and ammonoids were used in the experiment. Each cast was coated with a liquid plastic to obtain a smooth surface. The specimens were attached to the drag measuring device by a long stiff wire that was embedded into the aperture (Fig. 2).

The relationship governing the drag force on an object submerged in a moving fluid is:

$$D = C_D V^2 A \quad \frac{\rho}{2} \quad \frac{1}{N_R}$$

where:

C_D = the drag coefficient

D = the drag force

V = the velocity of the fluid

ρ = the density of the fluid, constant throughout the experiment

A = the cross-sectional area of the specimen normal to the direction of flow of the fluid

N_R = Reynolds number, considered constant for the ranges of velocities employed in the experiment

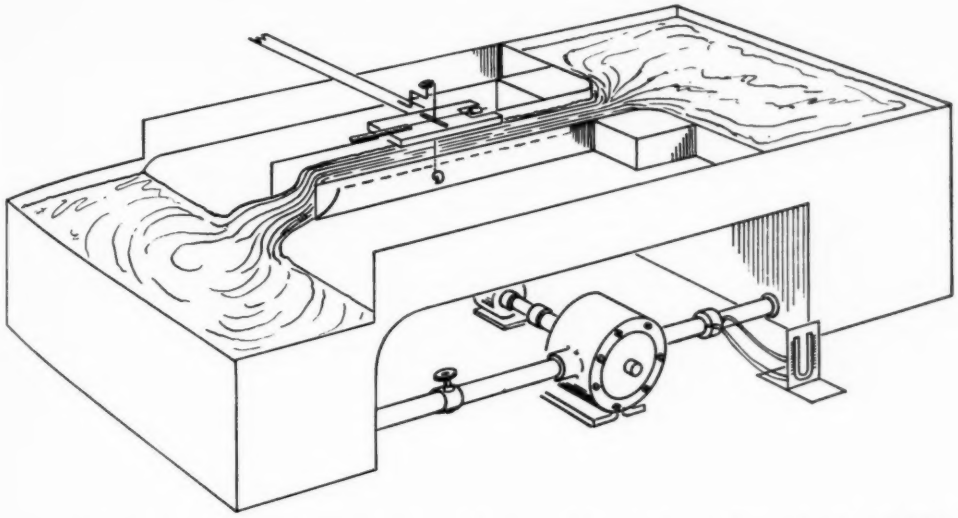

FIG. 1—Diagrammatic sketch of stream table and flume used in experiment. Approximately ×0.025.

Grouping the constants, the equation reads:

$$D=\frac{C_D'V^2A}{2} \quad \text{or} \quad C_D'=\frac{2D}{V^2A}$$

where:

$$C_D'=\frac{C_D\rho}{N_R}$$

Expressed in this form C_D', the measure of streamlining, is a dimensionless quantity independent of small changes in velocity

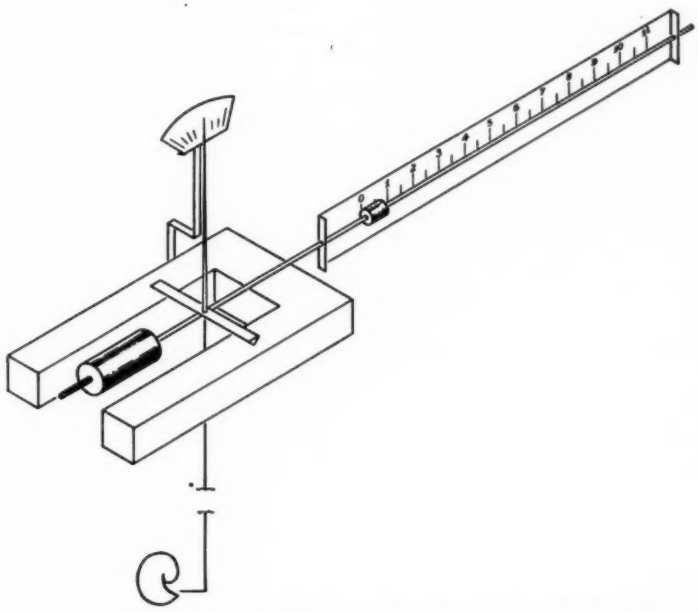

FIG. 2—Diagrammatic sketch of drag measuring device. Approximately ×0.1.

and is an inherent property of the shape of the object. It provides a means of comparing the hydrodynamic efficiency of the various specimens numerically.

It should be stressed that the numerical value of C_D' obtained from the above formula has no value by itself except when compared with the other specimens. Theoretically the value of C_D' for each of the five runs made on an individual specimen should be the same; however, due to experimental errors there are differences. The values of C_D' derived from data obtained at five different velocities of water were averaged to give an approximation of C_D' for each individual specimen to facilitate comparison. As a general rule the C_D' value decreases as the velocity decreases for any particular specimen. There are, however, numerous exceptions to this for which we have no explanation. In obtaining the averaged C_D' value those readings which appear out of place, that is, being much higher or lower than the other readings, were not used or were given less weight. Close agreement of three or more readings indicates the approximate area of the correct C_D' value plus a comparison with the values from similar conch forms. The limit of error on the calculated C_D' values is probably around 1.0.

For purposes of discussion the data of Table 1 can be grouped into three classes values of 13.0 to 15.4 including 13 specimens making the largest division. Values of C_D' of 16.0 to 16.6 make up the second group and include only 6 of the 21 specimens used. The last group includes only two specimens with C_D' values of 18.4 and 21.4. *Peltoceras* sp. has the highest averaged C_D' recorded (21.4) and thus the poorest streamlining. This species has a compressed, very evolute conch, with coarse ribs and large ventrolateral tubercles (Figs. 3Q, 4G). The extremely coarse ornamentation is confined to the outer volution, the inner volutions have finer, closely spaced radial ribs. The only other coarsely ribbed species used in the experiment is *Douvilleiceras* sp. which has coarse nodose radial ribs passing from the umbilical shoulder over the venter (Figs. 3T, 5C). This specimen gives a C_D' value of 16.4. *Douvilleiceras* is more involute than *Peltoceras* sp. and the whorl section is depressed, with a broadly arched venter. The specimen with the second highest C_D' value (18.4) is *Gastrioceras carbonarium* which has a smooth shell except for a row of small nodes on the subangular umbilical shoulder (Figs. 3S, 4H). The venter is broadly arched, sides convex, and umbilicus large and deep. The five individual runs of *Gastrioceras carbonarium* give calculated C_D', values ranging from 14.0 to 23.8, a difference of 9.8; this is by far the largest spread in C_D' values and we are dubious of the data on this species.

The middle group of C_D' values ranging from 16.0 to 16.6 includes species of *Dactylioceras*, *Cravenoceras*, *Columbites*, *Douvilleiceras*, and *Glaphyrites*. *Dactylioceras* sp. (Fig. 3O, 5L) and *Columbites parisianus* (Fig. 3M, 5I, K) have very similar conch types that are loosely coiled, the whorl sections are about as high as wide, the whorl sides have low radial ribs, and the venters are arched and smooth. *Glaphyrites welleri* has a smooth, depressed, widely umbilicate conch (Figs. 3R, 5F). The venter is broadly rounded, the umbilical shoulders acutely rounded with nearly vertical umbilical walls, and the umbilicus is wide and deep. *Douvilleiceras* has been referred to above. *Cravenoceras richardsonianum* is the most involute species of this middle group (Figs. 3N, 5E). The conch is involute, smooth and subglobular, the venter and whorl sides are broadly arched, the umbilical shoulders well rounded.

Dactylioceras, *Columbites*, and *Glaphyrites* are similar in their loosely coiled, widely umbilicate conchs. *Douvilleiceras* is more involute but the volutions are more rapidly expanding and the test bears coarse radial nodose ribs that cross the venter. *Cravenoceras* seems out of place in this grouping because of its smooth, rather involute conch.

The third group includes those specimens with C_D' values of 13.0 to 15.4 and includes species of *Perrinites*, *Shistoceras*, *Pseudocenoceras*, *"Nautilus" chesterensis*, *"N." collectus*, *Lytophiceras*, *Harpoceras*, *"Nautilus" subglobosus*, *Spathites*, *Joannites*, *Macrocephalites*, *Perisphinctes*, and *Scaphites*. Within this third group of 13 species three major conch types are present:

(a) involute, compressed forms with well rounded venters (*Pseudocenoceras* (Figs. 3I, 5J), *Perrinites* (Figs. 3P, 5G), *Shistoceras* (Figs. 3K, 5D), *Joannites* (Figs. 3A, 4A),

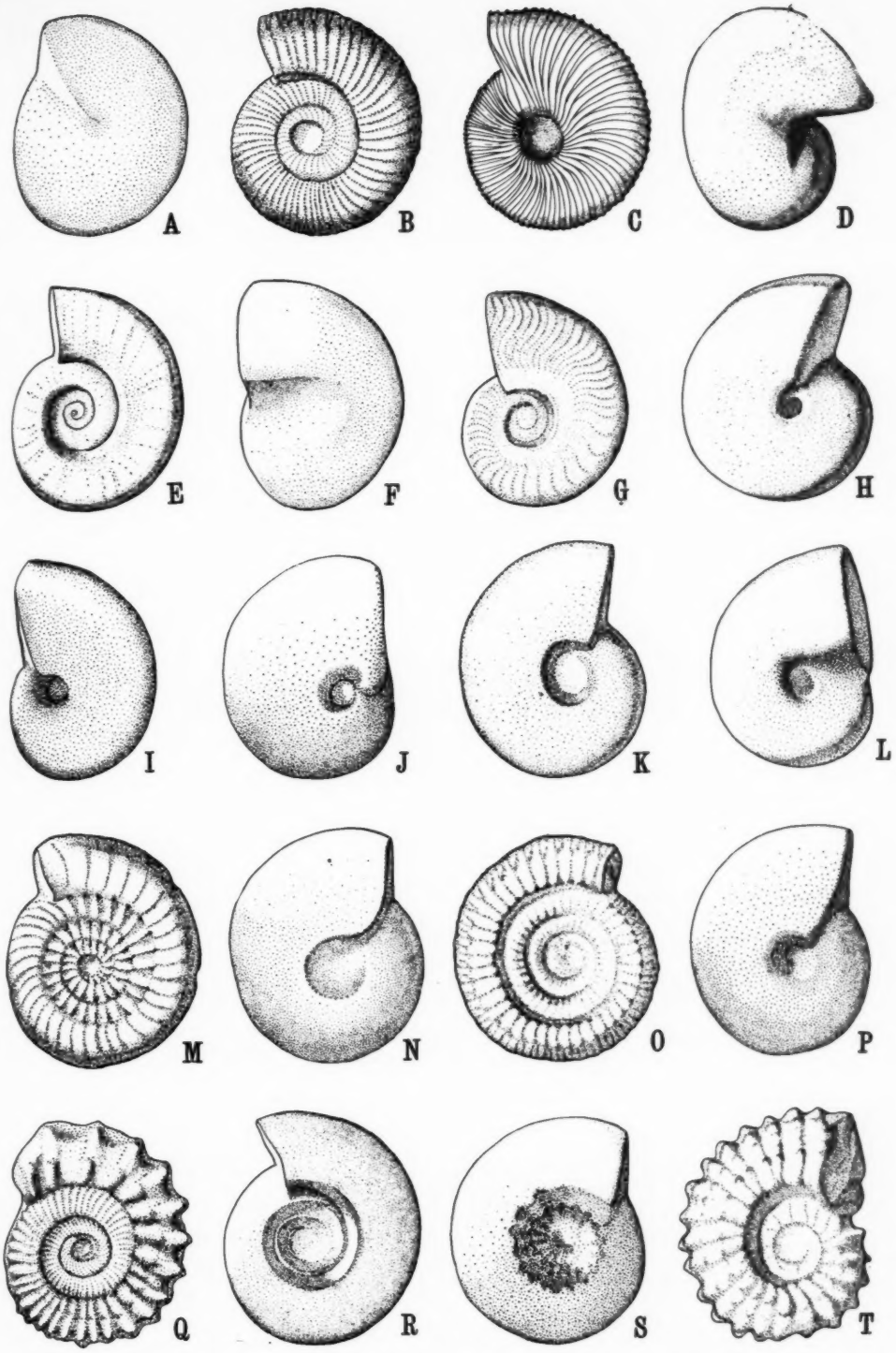

FIG. 3—Diagrammatic sketches of specimens used in experiment. A, *Joannites klipsteini*. B, *Perisphinctes* sp. C, *Macrocephalites* sp. D, *Scaphites aequalis*. E, *Ophiceras* (*Lytophiceras*) *commune*. F, "*Nautilus*" *subglobosus*. G, *Harpoceras subplanatum*. H, *Spathites chispaensis*. I, *Pseudocenoceras* sp. J, "*Nautilus*" *chesterensis*. K, *Shistoceras missourense*. L, "*Nautilus*" *collectus*. M, *Columbites parisianus*. N, *Cravenoceras richardsonianum*. O, *Dactylioceras* sp. P, *Perrinites hilli*. Q, *Peltoceras* sp. R, *Glaphyrites welleri*. S, *Gastrioceras carbonarium*. T, *Douvilleiceras* sp.

TABLE 1—NUMERICAL DATA FROM EXPERIMENTS

Specimen number	Species	A cm²	D gms force	V cm/sec.	C_D'	Averaged C_D'
1	*Peltoceras* sp. (Figs. 3Q, 4G)	20.1	4.38	19.9	21.4	21.4
			3.87	18.0	23.6	
			2.76	15.8	21.8	
			2.03	14.3	19.6	
			1.43	11.4	20.4	
2	*Gastrioceras carbonarium* (Figs. 3S, 4H)	23.2	4.91	19.1	23.8	18.4
			3.15	15.8	22.4	
			1.56	12.7	17.2	
			0.74	9.7	14.0	
			0.53	8.1	14.6	
3	*Dactylioceras* sp. (Figs. 3O, 5L)	14.5	2.11	18.5	17.4	16.6
			2.28	19.8	16.4	
			1.98	17.7	17.8	
			1.10	14.4	15.0	
			0.49	10.4	13.0	
4	*Columbites parisianus* (Figs. 3M, 5I)	9.0	1.72	22.0	18.2	16.6
			1.52	20.7	16.0	
			0.95	15.8	17.4	
			0.61	12.7	17.2	
			0.51	10.8	14.2	
5	*Columbites parisianus* (Figs. 3M, 5K)	11.1	1.58	19.4	15.6	16.4
			1.38	16.7	18.2	
			1.03	13.3	21.4	
			0.49	11.2	15.8	
			0.34	9.0	15.6	
6	*Douvilleiceras* sp. (Figs. 3T, 5C)	11.8	2.00	20.4	16.6	16.4
			1.49	18.1	15.8	
			1.28	15.9	17.6	
			0.92	13.7	16.8	
			0.58	11.3	15.6	
7	*Glaphyrites welleri* (Figs. 3R, 5F)	6.9	1.28	20.8	17.4	16.2
			0.99	18.8	16.6	
			0.60	14.7	16.4	
			0.41	12.6	15.2	
			0.31	10.7	15.8	
8	*Cravenoceras richardsonianum* (Figs. 3N, 5E)	8.8	1.46	21.2	15.6	16.0
			1.32	18.2	18.6	
			0.95	16.5	16.2	
			0.71	14.6	15.8	
			0.42	11.0	16.6	
9	*Perrinites hilli* (Figs. 3P, 5G)	10.4	2.27	23.8	15.8	15.4
			1.68	20.4	15.8	
			0.89	15.6	14.4	
			0.69	12.0	18.8	
			0.50	9.9	20.0	
10	*Shistoceras missourense* (Figs. 3K, 5D)	11.7	1.86	20.7	15.2	15.2
			1.30	17.6	14.8	
			0.86	14.2	15.0	
			0.59	11.6	15.4	
			0.42	9.8	15.4	
11	*Pseudocenoceras* sp. (Figs. 3I, 5J)	8.1	1.25	19.7	16.0	15.2
			0.78	16.3	14.6	
			0.67	14.4	16.2	
			0.45	12.4	14.6	
			0.34	10.6	15.2	

TABLE 1—(*continued*)

Specimen number	Species	*A* cm²	*D* gms force	*V* cm/sec.	C_D'	Averaged C_D'
12	*"Nautilus" chesterensis* (Figs. 3J, 5B)	20.0	2.50	18.7	14.6	14.8
			2.06	16.4	15.6	
			1.26	13.4	14.4	
			0.87	9.6	19.2	
			0.57	8.3	17.0	
13	*"Nautilus" collectus* (Figs. 3L, 5A)	15.2	2.34	20.4	15.2	14.8
			1.86	18.4	14.8	
			1.25	14.8	15.4	
			0.93	12.1	17.2	
			0.48	9.7	13.8	
14	*Ophiceras* (*Lytophiceras*) *commune* (Figs. 3E, 5H)	9.5	1.61	20.8	15.8	14.6
			1.26	17.3	17.8	
			1.01	15.2	18.4	
			0.58	13.3	14.0	
			0.44	11.6	14.0	
15	*Harpoceras subplanatum* (Figs. 3G, 4D)	8.0	1.43	22.4	14.6	14.4
			1.02	19.0	14.6	
			0.75	16.4	14.0	
			0.43	12.5	14.4	
			0.31	10.5	14.6	
16	*"Nautilus" subglobosus* (Figs. 3F, 4E)	19.2	2.46	18.8	14.8	14.2
			1.76	16.4	14.0	
			1.29	14.0	14.0	
			0.91	12.1	13.2	
			0.68	9.7	15.4	
17	*Perisphinctes* sp. (Figs. 3B, 4C)	8.5	1.36	20.4	15.6	14.0
			1.01	17.1	16.4	
			0.61	14.9	12.8	
			0.42	12.5	12.8	
			0.29	10.6	12.5	
18	*Spathites chispaensis* (Figs. 3H, 4I)	24.0	3.80	20.9	14.4	13.8
			1.29	12.0	15.2	
			1.74	15.0	13.2	
			2.54	18.2	13.0	
			3.31	20.3	13.6	
19	*Joannites klipsteini* (Figs. 3A, 4A)	13.3	1.94	21.3	13.2	13.6
			1.49	18.7	13.8	
			1.09	15.8	13.4	
			0.69	12.5	13.8	
			0.52	11.0	13.2	
20	*Macrocephalites* sp. (Figs. 3C, 4B)	9.2	1.38	21.6	13.2	13.6
			1.06	18.6	13.6	
			0.75	16.1	12.8	
			0.63	13.9	14.4	
			0.44	11.7	14.4	
21	*Scaphites aequalis* (Figs. 3D, 4F)	13.7	1.79	20.0	13.4	13.0
			1.24	17.3	12.4	
			0.92	14.8	12.6	
			0.67	12.1	13.8	
			0.29	9.8	11.8	

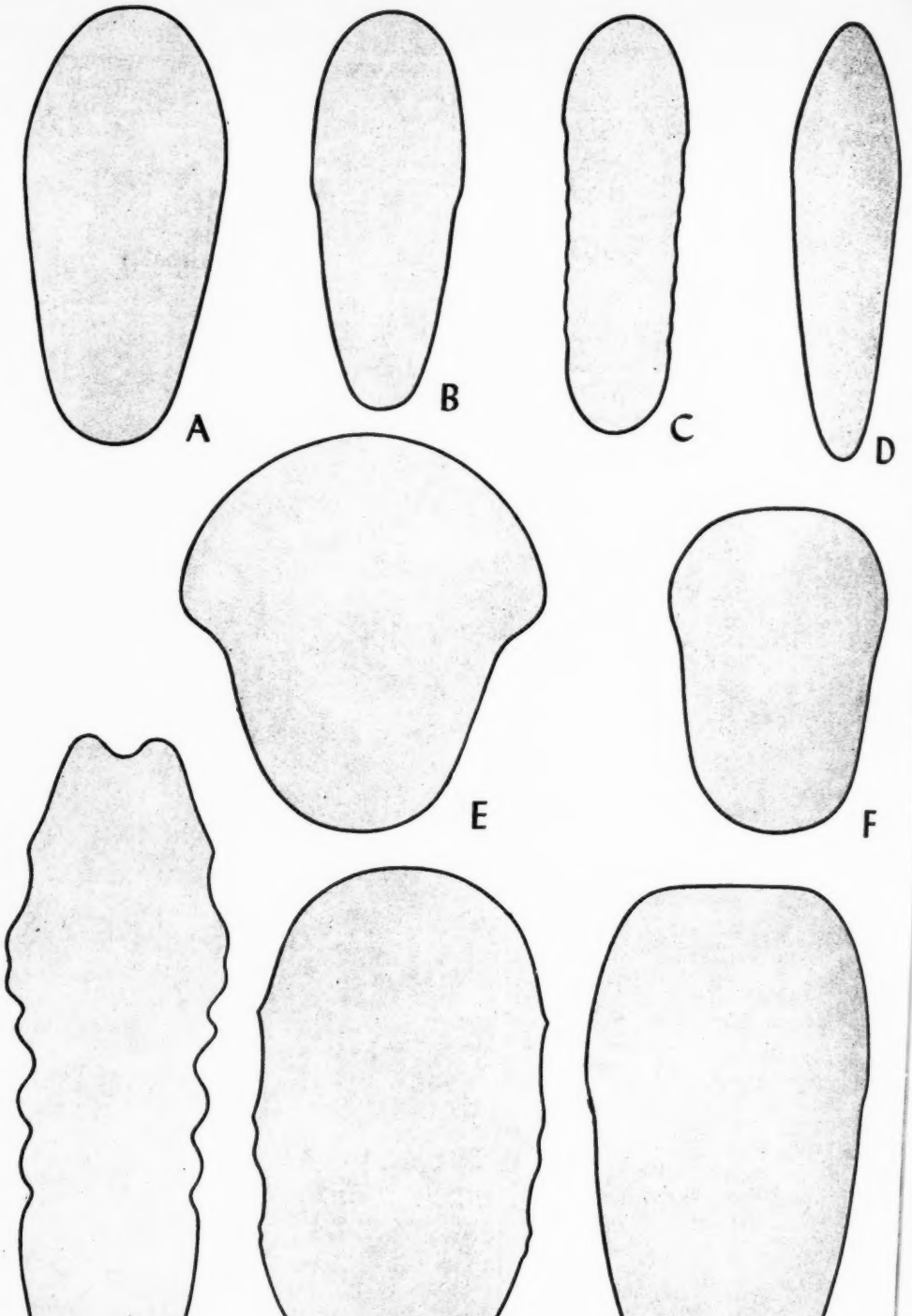

FIG. 4—Cross sections of the conch of specimens used in flume experiment. All figures ×1. A, *Joannites klipsteini*. B, *Macrocephalites* sp. C, *Perisphinctes* sp. D, *Harpoceras subplanatum*. E, "*Nautilus*" *subglobosus*. F, *Scaphites aequalis*. G, *Peltoceras* sp. H, *Gastrioceras carbonarium*. I, *Spathites chispaensis*.

and *Macrocephalites* (Figs. 3C, 4B),

(b) involute, subglobular, depressed conchs (*"Nautilus" collectus* (Figs. 3L, 5A), *"N" subglobosus* (Figs. 3F, 4E), *Scaphites* (Figs. 3D, 4F), *Spathites* (Figs. 3H, 4I), *"Nautilus" chesterensis* (Figs. 3J, 5B), and

(c) more or less evolute, very compressed conchs, *Lytophiceras* (Figs. 3E, 5H), *Harpoceras* (Figs. 3G, 4D), and *Perisphinctes* (Figs. 3B, 4C).

All of the species of this third group with relatively low C_D' values are characterized by involute conchs except *Harpoceras*, *Lytophiceras*, and *Perisphinctes*. These latter three genera have whorl sections that are higher than wide and rather broad but shallow umbilici. The species of the third group are likewise smooth except for *Harpoceras*, *Perisphinctes*, and *Macrocephalites* which have fine, low, adorally projecting ribs that cross the venter.

One of the generalizations that can be made from the data of Table 1 is that evolute forms tend to be less streamlined than involute forms. The cross-sectional shape of *Gastrioceras carbonarias* (Fig. 4H) is similar to that of *Spathites chispaensis* (Fig. 4I), the former has a large, deep umbilicus and a C_D' value of 18.4, the latter has a very small umbilicus, a more flattened venter, and a C_D' value of 13.8. Whereas there are significant differences in the character of the ventral shoulders between these two species, the most striking difference is in the width and depth of the umbilicus. *Dactylioceras* and *Columbites* have loosely coiled conchs, whorl sections that are equally wide or high and with radial ribs only on the whorl sides. Their cross-sectional shapes are illustrated on Figure 5I, K and L. *Columbites parisianus* shows much variation in the strength of the ornamentation and the degree of roundness of the ventral shoulders. Because of this, two specimens—one smooth type and one coarse type—were used in the experiment which gave C_D' values of 16.4 and 16.6 respectively. *Lytophiceras* (Fig. 5H), *Perisphinctes* (Fig. 4C) and *Harpoceras* (Fig. 4D) have cross-sectional shapes somewhat similar to *Dactylioceras* and *Columbites*, except for greater convergence of the whorl sides and more narrowly rounded venters. *Dactylioceras* and *Columbites* have broader and deeper umbilici. This seems to be the most significant factor in the rather wide discrepancy of their C_D' values. *Glaphyrites* and *Cravenoceras* have similar cross-sectional patterns (Figs. 5D, F) and C_D' values of 16.0 and 16.0 respectively. *Glaphyrites* has a wide, very deep umbilicus with angular umbilical shoulders. *Cravenoceras* has an involute, subglobular conch with a broadly arched venter. Its high C_D' value does not appear to be consistent with the other data.

GENERAL COMMENTS

It has long been believed that many ammonoids changed their mode of life during their ontogeny. Our experimental data tend to support this conclusion. The inner volutions of *Peltoceras* sp. are quite unlike the outer volution and are somewhat similar in form to the conch of *Perispinctes* sp. used in the experiment. *Peltoceras* sp. had a C_D' value of 21.4 and *Perisphinctes* sp. had a C_D' value of 14.0. Thus it seems that the young of *Peltoceras* were more efficient swimmers than the mature individuals. This factor could possibly have been overcome by the larger body and more efficient use of the hyponome of the mature individuals. The large ribs and nodes on the outer volutions of *Peltoceras* sp. could likewise have served to increase stability.

No specimens of *Nautilus* small enough for our flume were available to make the necessary plaster casts. *Pseudocenoceras*, *Shistoceras*, and *Perrinites* have conch forms very similar to that of modern *Nautilus* and these forms gave C_D' values of 15.2 and 15.4.

The living *Nautilus* at rest has its aperture turned slightly upward (Willey, 1897, fig. 24, p. 179; Dean, 1901, fig. 6, p. 828). Trueman (1941) has suggested the attitude of various ammonite shells at rest from determinations of the position of the centers of gravity and buoyancy. Serpenticones (loosely coiled shells) as *Dactylioceras*, *Caloceras*, and *Promicroceras* have the center of gravity and buoyancy very close together and were probably much less stable at a position of rest than *Nautilus*.

> It appears, therefore, that an ammonite with a serpenticone shell and high spiral angle may have been able to adopt a variety of attitudes, crawling on the sea floor by means of its tentacles, or swimming with its aperture turned upwards. (Trueman, 1941, p. 371)

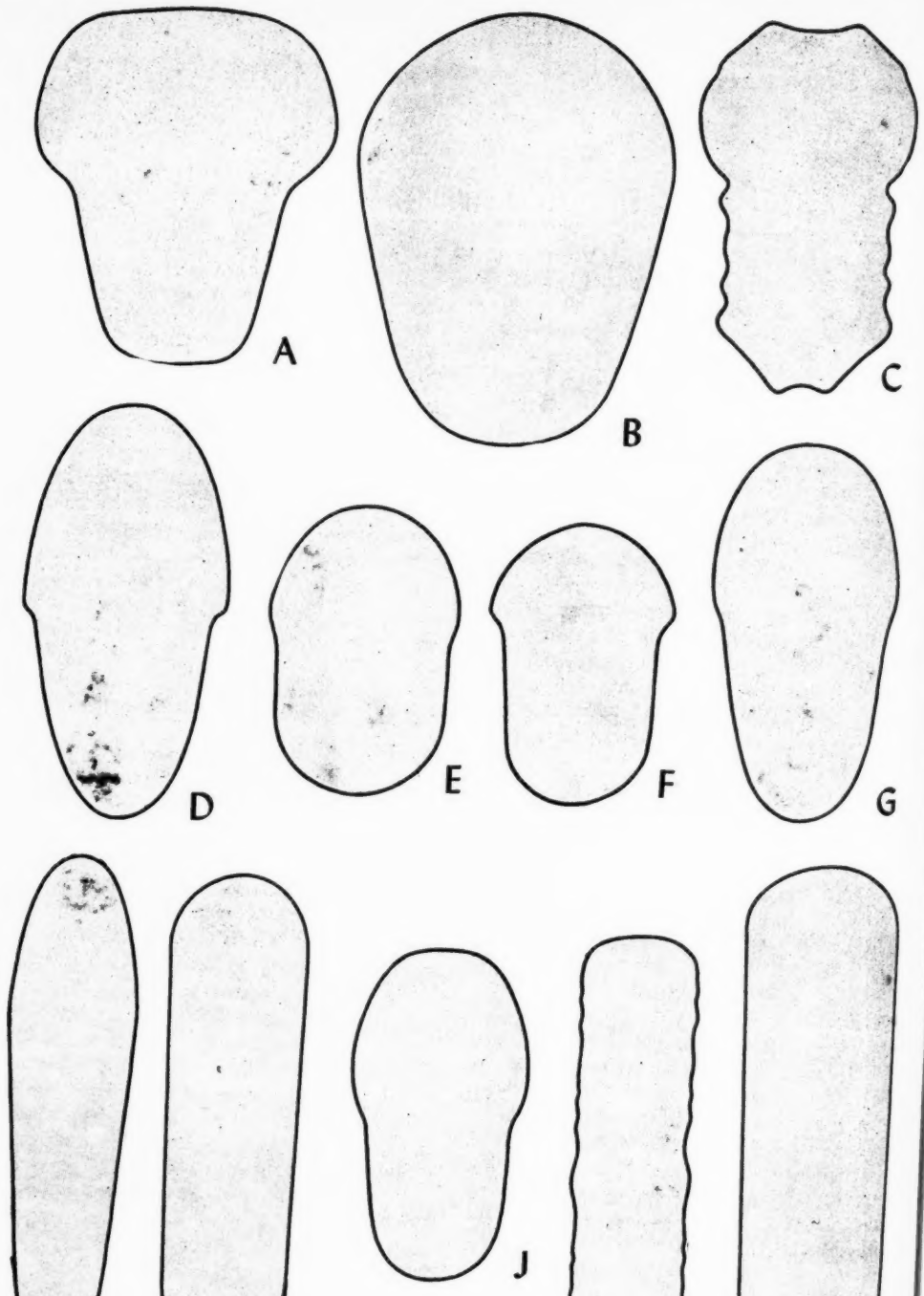

FIG. 5—Cross sections of the conch of specimens used in flume experiment. All figures ×1. A, *"Nautilus" collectus*. B, *"Nautilus" chesterensis*. C, *Douvilleiceras* sp. D, *Shistoceras missourense*. E, *Cravenoceras richardsonianum*. F, *Glaphyrites welleri*. G, *Perrinites hilli*. H, *Ophiceras (Lytophiceras) commune*. I, *Columbites parisianus*. J, *Pseudocenoceras* sp. K, *Columbites parisianus*. L, *Dactylioceras* sp.

Extension of the body forward, or the addition of extra calcareous deposits such as rostra, solid ribs, or aptychi, etc. would depress the upward tilt of the aperture. The hyponome of *Nautilus* is formed by two flaps of the mantle that overlap on the dorsal side. It is not known just how far the hyponome could be extended or change its direction. The tubular funnel of the squid and *Spirula* can be shifted through a large range of positions and enables a greater range in direction of movement. Schmidt (1930, p. 198) suggests that in many highly compressed ammonoids, as *Beloceras* and *Medlicottia*, the hyponome was confined to a very narrow space and was incapable of generating a large propulsive force. The very long body chamber of many ammonoids (the longidoma or makrodoma of authors) may have been mainly devoted to a larger mantle cavity wherein a longer, continuous propulsive force could be generated in the extrusion of water through the hyponome. Both Willey and Dean emphasized that *Nautilus* could not turn upside down, the positions of the centers of gravity and buoyancy calculated by Trueman for *Nautilus* support this observation. Our experimental data indicate that the serpenticones are relatively less streamlined than involute shells more or less like *Nautilus*. In terms of energy outlay for movement the cephalopod with a loosely coiled shell would expend more than one with an involute shell.

Calculations by Trueman (1941) on the relative volume of body chamber with air chamber for numerous ammonites showed ratios of 1:2 or 1:3, and ranging up to about 1:8. From these ratios Trueman concluded that

> an ammonite in which the ratio is greater than 1:3 is incapable of floating if its shell forms more than one-sixteenth of the total volume. It is rather striking, therefore, that in so many ammonites the shelly matter forms from one-tenth to one-fifteenth of the total bulk and the ratio is so frequently below 1:3. There appears to be striking evidence, therefore, that many ammonites were of approximately the same density as sea water (Trueman, 1941, p. 363).

The conch form of "*Nautilus*" *chesterensis*, "N" *collectus*, and "N" *subglobosus* suggest that they had ratios of body chamber to air chamber of much more than 1:3 and were probably denser than sea water. Their streamlining factors, however, are 14.2 and 14.8 which, in terms of our experiments, would indicate that they were more efficient swimmers than such forms as *Dactylioceras* or *Columbites* which had densities equal to that of sea water. Thus their high density is compensated by a more favorable streamlining factor.

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THE TRIANGULAR GRAPH IN POPULATION ANALYSIS—USES AND LIMITATIONS

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ABSTRACT—Use of the triangular diagram is explored for a large sample (n=828) of a single species, *Crurithyris planoconvexa*, collected from three successive time horizons. Where the closed curves embracing separate point clusters overlap, a "common core" is identified. This core contains the bulk of the total sample (n=815) and is interpreted to denote "persistence of cluster pattern through time" (i.e., non-subspeciation).

The distinction between *chronodeme* and *topodeme* is made in reference to published triangular graphs of *Pentremites* and *Anthracomya*. Limitations of the triangular diagram are considered and shown not to obscure evidence of subspeciation. The critical feature in interpreting overlapping curves is thought to be the relationship between the bulk of specimens and the "common core" (area of overlap): if inside the "core," then vertical subspeciation has not occurred; if outside the "core," a *chronodeme* is indicated. For samples from the same horizon, if outside the "core," *topodemes* (geographically separate populations) seem indicated.

Applications are made to problems involving lateral variation in a single species, the interrelations between species within a genus, and assignment of juveniles and adults of the same species to different species.

INTRODUCTION

A GRAPH of the Pennsylvanian brachiopod *Crurithyris planoconvexa* was prepared in an earlier study (Tasch, 1953, p. 367, fig. 3). This graph was a two-variable representation based on absolute size. Separate curves for length and width were drawn. The question arose at the time as to what extent the third variable, thickness, might influence the conclusions reached. Subsequently, the same data were used for plotting points on a triangular diagram. This paper presents the results and further considers the uses and limitations of the triangular diagram as an analytic device in population studies.

THE PLACE OF THIS STUDY

Heretofore in paleontology, triangular graphs have been used for comparatively small samples of from 40 to 55 specimens [Burma, 1948, p. 752, fig. 16, *Pentremites*, n=40; idem., fig. 19, based on Leitch's data, *Anthracomya*, n=55 (Leitch, 1940, p. 14)]. Leitch's data (1940) refer to "three chronodemes of *Anthracomya* taken from three horizons in ascending sequence" (Sylvester-Bradley, 1951, p. 98). A *deme* is an interbreeding population. Hence, *chronodemes* are such populations separated in time without regard to morphological changes (cf. Parkinson, 1954; pp. 377–378). It is assumed that Burma's data for *Pentremites* refer to *topodemes* (geographically distinct populations).

The distinction between *chronodeme* and *topodeme* (Sylvester-Bradley, 1951) was not available when Burma analyzed the triangular diagram for *Anthracomya* and *Pentremites*. Nevertheless, as will be shown later, it is an important consideration in such analysis. Even where the triangular graph for *Anthracomya* is reproduced subsequent to Sylvester-Bradley's work, it is accompanied by a non-critical discussion and recognition of the distinction noted is not made (Mayr, et al., 1953, p. 149).

The triangular graphs of small samples of *Anthracomya* and *Pentremites* led to the inference that the several "species" involved were really subspecies (Sylvester-Bradley, 1951, pp. 98–100) or distinct species (Burma, 1948, p. 755). This raises several questions. Can the triangular diagram and related graphic methods be of value in the study of a single species? What kinds of information can be obtained that will permit reasonable inferences, given the following: a large sample (hundreds of specimens) of the same species from successive horizons? Figure 1 indicates the results when a large sample (n=828) of the Pennsylvanian brachiopod,

Crurithyris planoconvexa was used. On this figure each point was derived by summing the chosen unit characters (length, width, and thickness). The percentage each character represents of the total was then found by simple calculation. Separate plots were superimposed on a single diagram and show successive time horizons (oldest-to-youngest: Dover P, Dry E, Dry C).

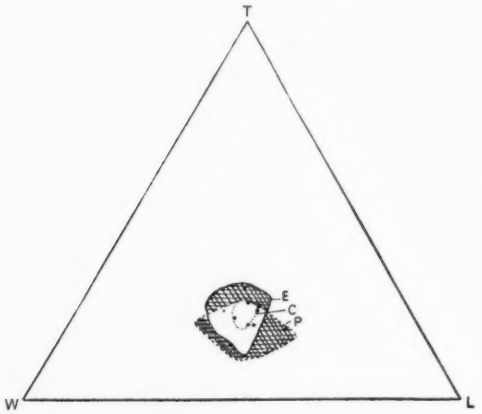

FIG. 1—Triangular graph for *Crurithyris planoconvexa*. Letters indicate successive horizons, oldest-to-youngest as follows: P = Dover P; E = Dry E; C = Dry C. The boundary line connecting peripheral points in a given point-distribution forms a closed curve: dashed line = Dover P; solid line = Dry E; dotted line = Dry C. Respective curves enclose all plotted points (cf. table 2). The common core is represented by unhatched area where all curves overlap or coincide. The cross-hatched portions of the curves indicate the area occupied by all points outside the common core. The large black dots indicate adult specimens. The rest of the sample (n = 820) consists of juveniles. Plotted points for juveniles and all the lines of the triangular graph are omitted for clarity. Each apex of the triangle represents 100 per cent and each side opposite, zero per cent. L = length, W = width, T = thickness. (For raw data, see Tasch, 1953, p. 357, fig. 1.)

GROWTH STAGES

When the two-variable representation (Tasch, 1953, fig. 3) was analyzed and reference made to other pertinent data, the conclusion was reached that the sharp single-peaked curves represented "a predominantly juvenile sample" (p. 371). For the Pennsylvanian of Nebraska, Dunbar and Condra (1932, p. 346) reported as the "normal size in many of our lots" of *C. planoconvexa*, a length of 8.0 mm. and a width of 8.5 mm. These were interpreted to be adults based on the graphic analysis referred to above (Tasch, 1953).

It seemed desirable to plot on a triangular graph, all specimens in the "Dry shale" fauna with a length of 8.0 mm. and over since these specimens would represent "adults" in the predominantly juvenile sample of the fauna and be size equivalents of a large part of the Nebraska material. Thus, two additional types of information would be provided by the graph. First, graphic representation would cover a larger portion of the species range, Nebraska as well as Kansas, and second, the graphic relationship between juvenile and adult specimens would be shown. Table 1 gives a tabulation of all specimens with a length of 8.0 mm. and over.

TABLE 1.—ADULT SPECIMENS OF *Crurithyris planoconvexa* IN DRY SHALE FAUNA WITHOUT REGARD TO LOCALITY
(N = 8)

Absolute size (mm.)			Proportions (%)		
L*	W	T	L	W	T
8.6	7.9	4.0	42.0	38.0	20.0
8.4	7.1	4.8	41.0	34.0	25.0
8.2	5.2	3.1	50.0	31.0	19.0
8.1	8.1	4.3	35.0	35.0	30.0
8.0	6.8	4.7	41.0	35.0	24.0
8.0	7.6	3.8	41.0	39.0	20.0
8.0	8.8	4.5	37.0	41.0	22.0
8.0	7.5	5.5	38.0	36.0	26.0

* L = length.
W = width.
T = thickness.

From figure 1 it will be seen that points for adults, when separately plotted, overlie those for juveniles. A triangular graph, therefore, as might have been expected, blurs the distinction between growth stages represented in a sample of a given species. However, it is this blurring effect which endows the triangular graph with special attributes. The proportional relationship between selected unit characters (length, width, thickness) of an individual is represented by a point on the graph. The spread of such proportion throughout the sample of the population will be broad or narrow.

However, for any given species, a distinct cluster of points can be anticipated. The point-clusters thus have value on the specific (or subspecific) level.

Not infrequently juveniles and adults of the same species have been assigned to different species. Among Pennsylvanian ammonoids, for example, it has been pointed out (Miller and Downs, 1950, p. 201) that minute differences due, among other reasons, to "ontogenetic stage represented" caused assignment of *Neodimorphoceras texanum* (Smith) specimens to a new species, *N. plummerae* Plummer and Scott. Several authors originally assigned immature species of *Goniolobоceras goniolobum* to either *Wiedeyoceras nodomarginatum* or to *W. pingue* (Miller and Downs, 1950, p. 197). An even more striking illustration is provided by the following finding: specimens of *Goniatites parrishi* Miller and Gurley, *Milleroceras minusculum* Miller, *Goniolobоceras discoidale* Böse, and *Goniolobоceras gracellenae* Miller and Cline "are the young of *G. goniolobum* or *G. welleri*" (Elias, 1938, pp. 91–100). *G. welleri* has since been placed in the synonymy of *G. goniolobum*. Thus, immature specimens, previously assigned to three different genera and three distinct species within one genus, *Goniolobum*, were found to belong to the same species of the same genus. Examples could be multiplied, thus, Ulrich's assignment of the young of some Mississippian blastoids to separate species (Burma, 1948, p. 750).

Separate clusters of points for adults and juveniles of the same species will show almost complete overlap on the triangular graph. While, for distinct but related species, overlap of point-clusters will be partial and involve only the margins of the cluster. A sizeable sample, of course, is a prerequistite for meaningful results. Use of the triangular diagram to resolve problems of this type can be of distinct aid to the taxonomist.

SUBSPECIATION (?)

Recognition of subspecies in the paleontological record of invertebrates is extremely difficult. Among other snares, how are horizontal subspecies to be distinguished from vertical subspecies when "differentiation of populations into geographic races is vertical evolution" (Newell, 1947)? The triangular graph offers a possible approach to the recognition of vertical subspecies.

Figure 1 shows that the point-cluster for the older shale (Dover P) is almost completely overlapped by the next younger shale (Dry E), and that the cluster of the youngest bed falls entirely within the overlapped portion of the Dover P and Dry E clusters. Where overlap of clusters of the same species from different time horizons involves the major, or total area of each cluster, it is unlikely that a vertical subspecies is represented. Because of this, some explanation is required for the portion of the cluster at a given time horizon (Dover P) not overlapped by the earlier cluster (Dry E), and of the new area embraced by the closed curve for Dry E. Apparently there is a dominant character to some point distributions. In figure 1 this is expressed by the portions of the respective closed curves which overlap. This common core of the successive point-distributions may be interpreted as representing persistence of cluster pattern. The crosshatched areas in figure 1 include relatively few individuals represented by actual points as compared to the bulk of the sample encompassed in the common core of the point-distribution. Table 2 shows the frequency.

TABLE 2.—FREQUENCY OF INDIVIDUALS REPRESENTED IN VARIOUS PORTIONS OF SUPERIMPOSED POINT-DISTRIBUTIONS*

Number of Specimens	Common Core[a]	Cross-hatched Area—Dry E[b]	Cross-hatched Area—Dover P[b]
828	815	10	3

* See Figure 1.
[a] Includes four specimens of Dry C. Each point represents from 1–36 individuals.
[b] Each point represents one individual.

A qualification seems necessary for the closed curves drawn to connect the peripheral points in a given point-distribution. It is assumed that any such curve embraces the probable area on the graph that would contain all additional points that might be plotted were a larger sample available. When a sizeable sample has been plotted

and the closed curve includes all points of such a sample, the likelihood is that it is a fairly close approximation of the areal pattern of a given population's point-distribution. Even when large samples are plotted, a straight-line connection between peripheral points in a given spread would indicate more correctly the areal pattern than would a closed curve. If points are few and relatively far apart, it is likely that the closed curve connecting such points would provide an areal pattern which, if a larger sample were available, would be found to be but a sector of a larger pattern.

These limitations do not negate the value of a triangular graph for certain uses. They must be kept in mind, nevertheless, and serve as a caution to the investigator in his interpretation of instances of overlap, etc. Where the common core is concerned, greater confidence can be placed in interpreting overlap as indicative of persistence of cluster-pattern. The fact that despite time horizons, the common core in figure 1 includes the bulk of specimens, reenforces this view.

Once the stated limitations of the triangular graph are taken into account, a further question arises. Does the degree of error inherent in this method of analysis preclude the possibility of making fine distinctions between one vertical subspecies and another? Several considerations bear on the answer to this question: (1) if the common core does not include the bulk of plotted points, it most likely will indicate vertical subspeciation (chronodemes) at one or more time horizons; (2) if it does include the bulk of plotted points for some but not all of the superimposed closed curves, then what appears to be indicated is subspeciation at the time horizon represented by the non-conforming closed curve and persistence of cluster-pattern, i.e., non-subspeciation for the other closed curves; (3) if the common core includes the bulk of plotted points for all superimposed closed curves, as in the case of *C. planoconvexa*, then subspeciation can be ruled out. Thus, the relationship between the bulk of plotted points and the common core seems to be the critical factor in determining whether there are vertical subspecies in the sample. For a large sample from successive horizons, the crudeness of the triangular diagram is unlikely to obscure the above-noted relationship.

The above conclusions were arrived at solely by reference to figure 1 and clarified somewhat by reference to figure 2, as will be discussed presently. It is of interest, therefore, and in the nature of an independent confirmation to consider the interpretation of Leitch's data by Sylvester-Bradley (1951). Sylvester-Bradley concluded that the three forms of *Anthracomya* "can be regarded as chronological subspecies of a single species." Since Burma had used Leitch's data earlier to plot a triangular graph, his graph of *Anthracomya* may be regarded as representing subspecies rather than, as he thought in agreement with Leitch, distinct species. Again, it will be seen that the distinction between topodeme and chronodeme is involved. Successive chronodemes will show the characteristic type of overlap of closed curves where, as in the case of *Anthracomya*, the bulk of plotted points lie outside a common core (cf. Burma, 1948, fig. 19). This points up the utility of the triangular graph as a method for detection of chronological subspecies.

Some discussion is warranted of Burma's interpretations of the closed curves in his *Anthracomya* and *Pentremites* diagrams. Interpretation of what he refers to as "a boundary line [that] encloses the field defined by each set of points" (p. 755)—the closed curve—must be carefully qualified. Some of the qualifications have already been discussed. In addition, some qualification is necessary in interpreting the shape of the curves. For blastoids, the shape tended to be "circular" while for the pelecypods it was "elongate." The elongation was thought to be related to mode of growth. Further, for the four species ("subspecies" of Sylvester-Bradley) of *Anthracomya*, the direction of elongation of some curves at right angles to others was thought to have possible meaning relative to different phyletic lines. It was noted that "data are not sufficient" to pursue these interpretations beyond the level he attempted.

The elongation and the direction of elongation of these "boundary lines" would be considerably altered or revised if, instead of a sample of $n = 55$, each curve bounded a set of points representing hundreds of speci-

mens. Thus, it seems unlikely that shape and orientation of curves can be used as valid indicators of biological factors. The evidence of the present paper suggests that more reliance can be placed on the area occupied by the bulk of plotted points relative to a common core, i.e., the area where all curves overlap. Even here it is doubtful whether concepts such as mode of growth can be appropriately considered.

For the problem at hand, figure 2 shows that only specimens of the older Dover P horizon have a percent length of 45 or greater (9 specimens out of 289). Similarly, only specimens of the younger Dry E horizon have a percent length of 35 or less (43 specimens out of 535). For a percent length of 44, Dry E specimens have a variation in percent width of 40–44 (3 specimens out of 535), while for Dover P, the variation is 34–40 (7 specimens out of 289). Out of a total sample of 828 specimens, 62 or seven percent, are involved in the part of the graph where coincidence or overlap of verticals does not occur. Table 3 gives the data on which figure 2 was plotted.

The persistence of cluster-pattern through time suggested by analysis of the triangular graph, can now be better understood in light of figure 2. Essentially, what appears to persist through time is range in variation of percent width where percent length is constant.

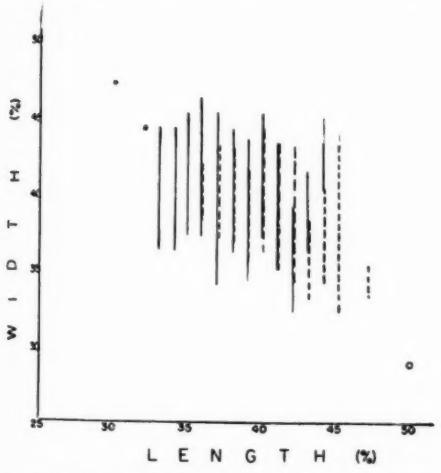

FIG. 2—Variation in percent width when percent length is held constant for specimens of *Crurithyris planoconvexa*. Solid line = Dry E (n = 535); dashed line = Dover P (n = 289). The dashed lines are offset slightly for clarity but actually are superimposed on the solid lines. Black dots indicate individual specimens from Dry E; circle dot indicates individual of Dover P. For frequencies see table 3.

APPLICATIONS TO FUTURE RESEARCH

Since this is an exploratory study based on data for a single species, it is desirable that other investigators test the procedures discussed above. In studies of lateral variation within a single species, the triangular graph can be tested. Specimens from respective collecting stations can be separately plotted for each station. The several cluster-patterns enclosed by boundary lines or closed curves can then be superimposed. Evidence of horizontal subspeciation (topodemes) may be revealed in this way.

A probable example of topodemes can be cited. On the graph for *Pentremites* (Burma, 1948, fig. 16), *P. pyriformis* is represented by a separate closed curve not overlapped by the curves for the other species. The curves for *P. godoni* A and *P. godoni* B overlap. Multivariate analysis led to the conclusion that A and B represented two species. Assuming that the three species coexisted at the same time, *P. pyriformis* can be interpreted as a topodeme. *P. godoni* A and B, together, constituted another topodeme. However, overlap of their curves indicates that geographic isolation between them *was not* complete. To resolve this matter, it would be necessary to have further information. Do the bulk of plotted points occur inside or outside the common core formed by the overlapping portion of each curve? If they are inside, the likelihood is that gene flow existed between these two populations. In that case, the stage of speciation would not have been attained.

For taxonomic work, the triangular graph would seem a useful aid in checking and clarifying on the generic level. Thus, interrelations between species within any given genus previously inferred by morphologic criteria can be verified.

Wherever in the geologic column large well-preserved samples of fossils are available from successive time horizons (Foraminifera, including fusulinids, Tertiary mollusks, faunas of Carboniferous cyclothems, etc.) investigators can contribute to pointing out

TABLE 3.—PERCENTAGE CALCULATION (BASED ON SUM OF CHARACTERS) FOR INDIVIDUAL SPECIMENS OF *Crurithyris planoconvexa*

Figures 1 and 2 were plotted from these calculations
L = length, W = width, T = thickness, f = frequency

L (%)	W (%)	T (%)	f	L (%)	W (%)	T (%)	f
Dry E (N = 535)							
44	44	12	1	38	40	22	31
44	42	14	1	38	39	23	21
44	40	16	1	38	38	24	11
43	41	16	1	38	37	25	1
43	39	18	2	38	36	26	1
43	38	19	1	37	45	18	1
43	37	20	1	37	44	19	2
43	36	21	2	37	43	20	2
42	39	19	5	37	42	21	6
42	38	20	2	37	41	22	35
42	35	23	1	37	40	23	29
42	34	24	1	37	39	24	8
42	32	26	1	37	38	25	7
41	42	17	2	37	34	29	1
41	41	18	2	36	46	18	1
41	40	19	4	36	45	19	1
41	39	20	6	36	44	20	1
41	38	21	5	36	43	21	7
41	37	22	4	36	42	22	14
41	35	24	2	36	41	23	22
40	45	15	1	36	40	24	21
40	43	17	2	36	39	25	10
40	42	18	7	36	37	27	1
40	41	19	11	35	45	20	1
40	40	20	14	35	43	22	6
40	39	21	12	35	42	23	11
40	38	22	11	35	41	24	8
40	37	23	6	35	39	26	1
39	43	18	2	35	38	27	1
39	42	19	11	35	37	28	1
39	41	20	19	34	44	22	1
39	40	21	15	34	43	23	2
39	39	22	24	34	42	24	1
39	38	23	10	34	41	25	4
39	37	24	9	34	38	28	1
39	36	25	1	34	36	30	1
39	34	27	1	33	44	23	1
38	44	18	2	33	39	28	1
38	43	19	1	32	44	24	1
38	42	20	18	29	46	25	1
38	41	21	36				
Dover P (N = 289)							
50	29	21	1	44	34	22	2
47	35	18	1	44	35	21	2
47	32	21	1	44	36	20	1
45	32	23	2	44	37	19	1
45	34	21	1	44	40	16	1
45	36	19	1	43	35	22	2
45	37	18	1	43	38	19	1
45	44	11	1	43	36	21	2

TABLE 3—(*continued*)

L (%)	W (%)	T (%)	f	L (%)	W (%)	T (%)	f
Dover P (N = 289) *continued*							
43	37	20	2	40	37	23	13
43	33	24	1	40	39	21	15
43	34	23	1	39	37	24	4
42	42	16	3	39	42	19	4
42	43	15	1	39	41	20	4
42	34	24	1	39	40	21	8
42	41	17	3	39	38	23	16
42	40	18	5	39	39	22	17
42	39	19	5	39	36	25	1
42	35	23	5	39	43	18	1
42	37	21	9	38	40	22	2
42	36	22	9	38	37	25	1
42	38	20	8	38	36	26	1
41	43	16	1	38	43	19	1
41	35	24	1	38	38	24	5
41	42	17	2	38	39	23	5
41	41	18	3	38	41	21	5
41	36	23	7	37	37	26	2
41	39	20	8	37	38	25	1
41	40	19	9	37	43	20	1
41	37	22	11	37	42	21	1
41	38	21	20	37	39	24	5
40	43	17	2	37	41	22	8
40	42	18	1	37	40	23	4
40	44	16	1	36	38	26	2
40	41	19	2	36	39	25	1
40	36	24	3	36	41	23	4
40	38	22	11	30	53	17	1
Dry C (N = 4)							
41	34	25	1	38	42	20	1
40	41	19	1	35	40	25	1

additional strengths and weaknesses of the type of analysis given here.

Finally, it is hoped that as more data become available through use of the triangular graph, this method will then be amenable to more rigorous mathematical analysis.

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JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 1, PP. 178–187, 6 TEXT-FIGS., JANUARY 1955

PALEONTOLOGICAL NOTES

A NEW SPECIES OF *ENDOLOBUS* (NAUTILOIDEA) FROM THE CLORE LIMESTONE (CHESTER) OF WESTERN KENTUCKY

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ABSTRACT—A large, long-chambered representative of *Endolobus* is described as *E. clorensis*, n. sp.

THROUGH the courtesy of Professor H. R. Wanless of the University of Illinois, a representative of the genus *Endolobus* from the Clore limestone (Chester) of western Kentucky has been made available for study. It is the first member of the genus to be described from a precise stratigraphic and geographic locality in the Chester series. Although the specimen is poorly preserved it retains sufficient diagnostic features to indicate that it represents a new species of *Endolobus*. For a general treatment of the genus the reader is referred to Miller and Youngquist's 1949 monograph "American Permian nautiloids."

SYSTEMATIC DESCRIPTION

ENDOLOBUS CLORENSIS Collinson, n. sp.
Text-figures 1–3

The large individual upon which the new species is based is an internal mold preserved in argillaceous gray limestone. It represents three-fifths of a whorl some 210 mm. at greatest diameter. The specimen expands rapidly orad, is only slightly impressed dorsally, and is considerably depressed. At the adoral end it is reniform in cross section. The maximum height and width of conch are estimated to be 85 and 170 mm. respectively. The umbilical walls are very steep and the umbilicus appears to have been broad, deep, and perforate. On the ventral part of the whorl there are faint traces of what appear to be growth lines. They form a broad, deep, tongue-shaped ventral sinus and broadly rounded salients on the lateral margins. Along the lateral zones on either side of the conch, there are low, inconspicuous, slightly elongate nodes of which there are 10 or 11 per whorl.

The sutures are simple and only slightly sinuous (fig. 3A). They form very broad shallow ventral lobes, broad but more narrowly rounded lateral saddles and broad shallow subangular dorsal lobes each of which is divided by a relatively small, tongue-shaped, median dorsal lobe. The camerae are exceptionally long; it is estimated that there are only 14 of them to a volution. The septa are essentially transverse and are convex apicad. The siphuncle is exposed in the next to last septum preserved (fig. 2) and a longitudinal section was made of the third from last chamber. The siphuncle is orthochoanitic (fig. 3B) and it measures 11 mm. in diameter where the conch is 74 mm. high and 148 mm. wide. It is positioned 33 mm. from the dorsum. The septal necks are straight and their length is about a fifth that of the camerae. The connecting rings are nearly cylindrical in shape and are only slightly expanded within the chambers.

Remarks.—Two characteristics readily distinguish *Endolobus clorensis* from all other representatives of the genus: the exceptionally long camerae and the large size of conch. Insofar as can be determined no other species possesses camerae of length comparable to those of this species. Only one, the type species of *Endolobus*, is known to approach or exceed *E. clorensis* in size. The type species differs, however, in that there are about twice as many chambers per whorl, the lateral zones of the conch are more narrowly rounded and the sutures possess ventral saddles.

E. greenbrierensis Miller and Collins

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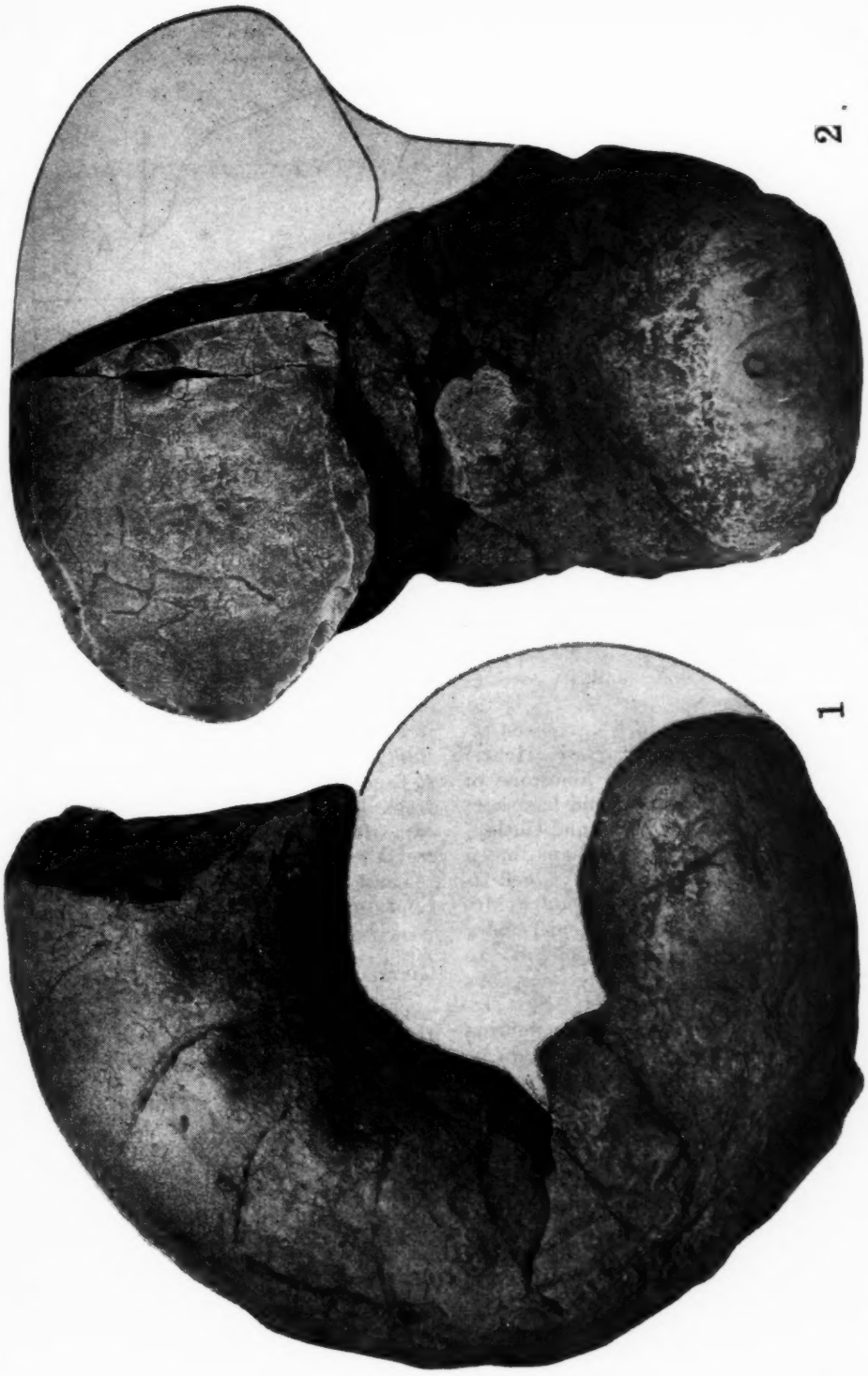

FIGS. 1, 2—*Endolobus clorensis* Collinson, n. sp. *1*, Lateral view of holotype, ×1½. *2*, Apertural view of holotype with the two most adoral chambers removed, ×1½. From the Clore limestone 2 miles northeast of Scottsburg, Kentucky.

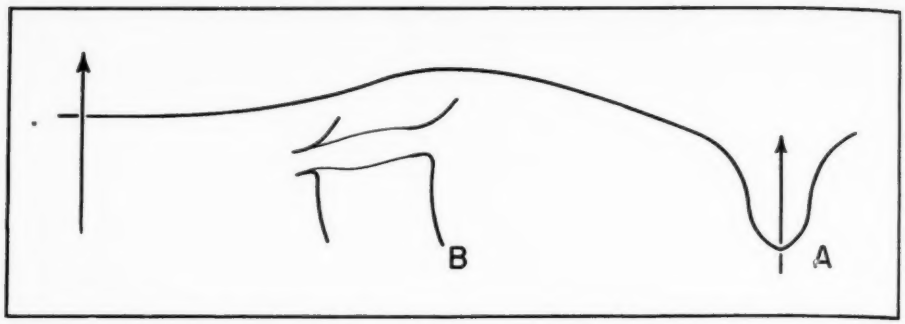

FIG. 3—*Endolobus clorensis* Collinson, n. sp. Diagrammatic representations of (A) the adoral suture shown in figure 2, and (B) a median longitudinal section of the third from last adoral camera of the holotype. Both ×½.

(1947), from the Greenbrier limestone of Pennsylvania, is a moderately large species and its general physiognomy is much like that of the one under study, but it possesses very short camerae. *E. ornatus* Girty (1911), from the Moorefield shale of Arkansas, appears to be related to *E. clorensis*, but the relationship may be more apparent than real for the Arkansas species is known only from a living chamber and a single septum. In addition to being very small, it possesses numerous fine lirae.

Of the other species which have been referred to *Endolobus*, *E. depressum* (Hyatt) (1891), from the Fort Scott limestone of Kansas, is greatly depressed and has short chambers. *E. greenensis* (Miller and Gurley) (1897), from the Chester of Indiana, has a very narrowly rounded venter as well as short chambers. *Nautilus forbesianus* McChesney, which Miller, Dunbar and Condra (1933, p. 194) believed to be referable to *Endolobus*, does not belong in the genus because it possesses no dorsal lobe (McChesney, 1868, p. 51). A careful examination of the holotype of *Nautilus* (*Temnocheilus*) *coxanus* Meek and Worthen (1866) reveals that it, too, has no dorsal lobe.

Although *E. clorensis* is at present known from only the holotype, reports of at least two other specimens seen in the field by Professor Wanless and his students indicate that the species may not be rare in western Kentucky. The simple form of the species, accompanied by poor preservation, has undoubtedly contributed to its being overlooked by previous field parties.

Occurrence.—Clore limestone in Illinois Central Railroad cut one-fourth mile east of Stuart Weller's cross section of Walche's Cut (Weller, 1923, figure opposite p. 100), east central part of Princeton Quadrangle, near Claxton, Caldwell County, Kentucky. The holotype was found loose on the south side of the tracks at the base of the cut, which is only ten feet high. The matrix of the specimen matches the lithology of the rocks one to three feet above the tracks, and there is no good reason to doubt that it came from that zone. The *Batostomella nitidula* zone which occurs near the base of of the Clore was found about ten feet below track level. Thus the specimen probably came from a horizon between 11 and 14 feet above the *Batostomella* zone.

Holotype.—University of Illinois collections.

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AN UPPER CAMBRIAN CORAL FROM MONTANA

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ABSTRACT—A new genus and species, *Cambrophyllum problematicum*, is described from a single specimen from the *Cedaria* zone of the Maurice formation of Montana and is probably referable to the Schizocoralla.

Genus CAMBROPHYLLUM Fritz & Howell, n. gen.

Cambrophyllum is based upon a single specimen found in the *Cedaria* zone of the Maurice formation, lower Upper Cambrian (lower Dresbachian) of Montana. The fossil, at first thought to be a bryozoan, was collected by Peter Verrall, a graduate student at Princeton University.

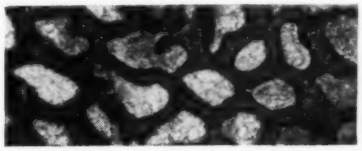
Diagnosis.—The corallum, a small, subhemispherical mass, is composed of slightly twisted, polygonal to round corallites; walls thick, imperforate, those of adjacent corallites amalgamated. Relatively stout, blunt processes, of varying lengths, project from the walls into the corallites; these structures are interpreted as agents in the process of fission. Where fission is incomplete communication between adjacent corallites may be noted. Tabulae absent.

Type species.—*Cambrophyllum problematicum* Fitz and Howell, n.sp.

CAMBROPHYLLUM PROBLEMATICUM Fritz & Howell, n. sp.
Figures 1, 2

External features.—Holotype corallum a small, subhemispherical mass 10 mm. wide at base; maximum width observed 30 mm.; maximum height 15 mm. These measurements are approximate only since part of the colony, possibly a quarter, has been destroyed by erosion.

Transverse section.—Corallites polygonal to slightly rounded and variable in size, an average of approximately three in 3 mm. Walls of contiguous corallites relatively thick, reduced now to a calcareous, crystal-



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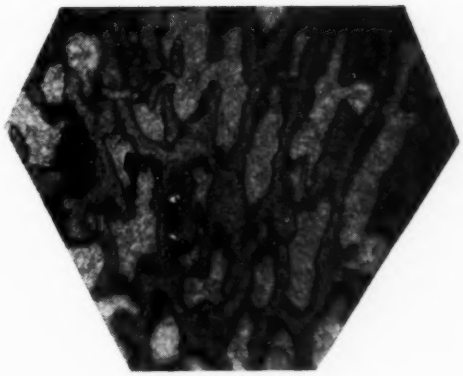

2

FIGS. *1, 2*—*Cambrophyllum problematicum* Fritz & Howell, n. gen., n. sp. *1*, Transverse section, ×6. *2*, Vertical section, ×6.

line mosaic; each corallite ringed by a thin, dense membrane. Stout, blunt processes, in various degrees of development, project into the corallites. These projections consist of the dense, inner tissue as well as part of the outer, now crystallized, portion of the wall. Not more than one of these blunt, spiniform structures is seen in an individual corallite. These structures simulate the pseudosepta of the Schizocoralla, as demonstrated by the Silurian species, *Multisolenia tortuosa* Fritz (1937), although, in the present instance they are much sturdier and less frequent. We assume, from the composition of their tissue and from the various stages of development represented, that they participated in the process of simple fission.

Vertical section.—Corallites consist of long, slightly twisted tubes, the thin, dark, "thecal" membrane in places exhibiting irregular crenulation. The processes from the walls into the corallites are not as clearly marked as in transverse section but may be detected; their radial nature is not clearly shown. Passages from one corallite to another are seen to advantage where the wall is lacking; this circumstance may be due to incomplete fission. Tabulae are absent.

Remarks.—Having only one example of this interesting and unusual fossil, thin sections were prepared with considerable trepidation. Naturally we wished to save as much as possible of the specimen. Furthermore, the fossil being small and weathered, it was not easy to obtain exact faces for sectioning in the directions desired. In spite of these difficulties, however, two fairly adequate transverse and vertical sections were secured, which permitted an interpretation of the internal structure.

In considering the presence of Anthozoa in the Cambrian, reference must be made to the genus *Mackenzia* which Walcott (1911) described from the Burgess shale as a holothurian but which later A. H. Clark (1913) placed in the Zoantharia; this soft-bodied, solitary organism Clark regarded as being related to the burrowing actinarian genus *Edwardsia*. Aside from their possible anthozoan affinities, no relationship is apparent between *Mackenzia* and *Cambrophyllum*.

No fossil described to date from the Cambrian can be directly compared with the present form. The only other genus of similar age and of somewhat comparable colonial growth is *Archaeotrypa* Fritz (1947, 1948). Two species of this genus were described from the *Cedaria* zone of the upper Cambrian of the foothills of British Columbia. While regarded as the oldest and most primitive bryozoan, it was suggested by the author that *Archaeotrypa* might conceivably be a primitive coral. The *Archaeotrypa* colonies are much smaller than *Cambrophyllum*, as are likewise the individual tubes; furthermore, the intimate morphology is quite different so that only a superficial resemblance exists.

Passing into the Ordovician it will be remembered that authenticated colonial corals appear first in the Chazy, the genus *Lamottia* Raymond (1924–26), now regarded as an exact synonym for *Lichenaria* Winchell and Schuchert (1895), being the oldest known example. *Lamottia*, as described by Raymond, is characterized by massive coralla; prismatic, thin-walled corallites with numerous tabulae but without septa or mural pores. A perusal of these characteristics and those of *Cambrophyllum*, as outlined above, leaves little doubt of the dissimilarity of the two genera.

Another Middle Ordovician genus, *Tetradium*, might be mentioned in this review of the oldest, possibly related forms. Here we have massive coralla, tiny tabulate corallites with regular, lamellar, vertical plates projecting from the wall; without mural pores. The most significant of these features in relation to *Cambrophyllum* is the presence of the septal processes; but in our new genus these structures do not appear to have marked vertical extent, are stouter and blunter, more irregular and less numerous. Their presence, however, as possible agents in the process of simple fission lead us to the conclusion that *Cambrophyllum* may belong to the subclass Schizocoralla. A new order of this latter group would be necessary, however, to include our Cambrian form; but the erection of such is probably premature. Furthermore, an attempt to consider the rôle that this new genus may have played in the phylogeny of the Anthozoa seems idle speculation at the present time.

Occurrence and horizon.—Intraformational pebble conglomerate near base of Maurice

formation, *Cedaria* zone, lower Dresbachian, lower Upper Cambrian, 50 feet east of dirt road in SW¼ NW¼ sec. 33, T. 3 N., R. 3 E., Horseshoe Hills, Montana.

Holotype.—Princeton University 76262.

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MANUSCRIPT RECEIVED JUNE 4, 1954

FAUNA OF THE KANOUSE SANDSTONE AT HIGHLAND MILLS, NEW YORK

CECIL H. KINDLE AND SEYMOUR H. EIDMAN
The City College, New York, N. Y.

ABSTRACT—A fauna of 35 species and varieties is listed from the Kanouse sandstone. This is more prolific than any fauna previously reported from the formation and is sufficient to show that the Kanouse is distinct from the Schoharie-Esopus below.

The Erie railroad cut at Highland Mills, Orange Co., N. Y., is well known for its exposures of Oriskany, Esopus, and Schoharie strata. Not so well known, however, is a younger sandstone which outcrops along the track about 1 mile farther north. The numerous fossils therein show it to be the Kanouse sandstone which Weller correlated with the Onondaga. Some of the early workers confused this sandstone with the Oriskany because of the lithologic similarities (Eckel, 1902; Darton, 1894; Hartnagel, 1907).

Willard, observing the Kanouse at its type locality near Newfoundland, N. J., in the Green Pond Mountain region, found the beds disconformably underlain by Decker Ferry limestone of Upper Silurian age. In the Delaware valley, near Port Jervis, Willard noted a disconformity at the base of the Schoharie-Esopus shales. On the basis of this stratigraphic evidence, coupled with the fact that the sparse Kanouse fauna at Newfoundland is one that could be of either Schoharie-Esopus or Onondaga age, both Willard (1937), and subsequently Cooper (1942), correlate the Kanouse sandstone with the Schoharie-Esopus shales.

That this correlation is erroneous is borne out by the stratigraphy at Highland Mills, in view of the fact that the Kanouse is here underlain by Schoharie grit which contains *Cypricardinia planulata*, *Conocardium cuneus*, and *Anchiopsis anchiops* var. *sobrinus*. The Kanouse is a massive, fine-grained conglomerate below, with pebbles averaging ¼ inch in diameter, and a thinner-bedded sandstone above. Thirty-five species, 28 of which are new to the formation, make up its fauna. Several of these may represent new forms. The fauna is essentially that of the Onondaga limestone, with most forms attaining a relatively large size.

A distinct coral facies, principally of *Zaphrentis*, is the dominant feature, with *Pleurodictyum*, *Cystiphyllum*, and *Heliophyllum* also present. Among the brachiopods, *Amphigenia elongata*, *A. elongata* var. *undulata*, and *A. curta* are the most abundant, with *A. elongata* reaching a length of almost 4 inches. *Atrypa reticularis* and *Meristella nasuta* are generally quite large and robust. *Spirifer? duodenarius* and *S. macra* are the most abundant of the spiriferoids, while the large and distinctive *S. macrothyris* is encountered less often. *Rhipidomella musculosa* var. *solaris*, an exotic form from the Moose River sandstone of

Maine, recognized by its enormous adductor scar, is encountered quite frequently as is *Megastrophia hemispherica*, a large, robust and strongly convex form.

Probably the most noteworthy feature is the abundance of the trilobite *Anchiopsis anchiops*. This form is recognized by the upturned caudal spine of the pygidium and moderately long occipital spine, in comparison with the variety *A. a. sobrinus* of the underlying Schoharie, in which the occipital spine is lacking. Among the pelecypods, *Conocardium cuneus* and *C. trigonale* predominate, whereas *Cypricardinia planulata*, so abundant in the Schoharie, is absent. *Cornellites flabellum*, a Hamilton form, is fairly common.

Thus, it would appear that the Kanouse sandstone represents a near-shore facies of the Onondagan sea, deposited contemporaneously with the Onondaga limestone of the Catskill and Schoharie regions.

FAUNAL LIST FROM FORMATIONS ALONG THE ERIE RAILROAD TRACK NEAR HIGHLAND MILLS, N. Y.

aa = very abundant, a = abundant, c = common, r = rare

Kanouse sandstone

Scaphopoda
- a *Tentaculites* sp. undet.

Corals
- aa *Zaphrentis* sp. undet.
- c *Cystiphyllum* sp. undet.
- c *Pleurodictyum* sp. undet.
- r *Heliophyllum* sp. undet.
- r *Favosites* sp. undet.

Brachiopoda
- a *Rhipidomella musculosa* var. *solaris* Clarke
- c *Platyorthis* sp. undet.
- c *Protoleptostrophia perplana* (Conrad)
- c *Schuchertella pandora* (Billings)
- c *Megastrophia hemispherica* (Hall)
- a *Eodevonaria arcuata* (Hall)
- a *Stropheodonta demissa* (Conrad)
- a *Spirifer? duodenarius* (Hall)
- c *S. macra* Hall
- r *S. macrothyris* Hall
- r *S. subcuspidatus* var. *lateincisus* Scupin
- c *Elytha fimbriata* (Conrad)
- c *Atrypa reticularis* (Linné)
- c *Meristella nasuta* (Conrad)
- a *Amphigenia elongata* (Vanuxem)
- a *A. elongata* var. *undulata* Hall
- a *A. curta* (Meek and Worthen)
- r *Prionothyris* sp. undet.

Pelecypoda
- a *Conocardium cuneus* (Conrad)
- a *C. trigonale* Hall
- c *Cornellites flabellum* (Conrad)
- r *Limoptera* sp. undet.
- r *Actinopteria decussata* Hall

Gastropoda
- r *Diaphorostoma lineatum* (Conrad)
- c *Pleurotomaria* sp. undet.

Cephalopoda
- r *Orthoceras? luxum* Hall
- r *Cyrtoceras? eugenium* Hall

Trilobita
- a *Anchiopsis anchiops* (Hall)
- r *Phacops cristata* var. *pipa* Hall

Schoharie grit

Corals
- r *Zaphrentis* sp. undet.

Brachiopoda
- r *Orbiculoidea* sp. undet.
- a *Schuchertella pandora* (Billings)
- a *Eodevonaria arcuata* (Hall)
- r *Stropheodonta demissa* (Conrad)
- c *Spirifer? duodenarius* (Hall)
- c *S. macra* Hall
- r *S. macrothyris* Hall
- c *Elytha fimbriata* (Conrad)
- c *Leptocoelia acutiplicata* (Conrad)
- r *Meristella nasuta* (Conrad)

Pelecypoda
- aa *Cypricardinia planulata* (Conrad)
- r *Conocardium cuneus* (Conrad)

Trilobita
- c *Anchiopsis anchiops* var. *sobrinus* (Hall)
- r *Phacops cristata* var. *pipa* Hall
- r *Proetus folliceps* Hall and Clarke

Esopus shale

Incertae sedis
- *Taonurus caudagalli*

Oriskany quartzite

Brachiopoda
- c *Eodevonaria arcuata* (Hall)
- c *Anoplia nucleata* (Hall)
- r *Platyorthis planoconvexa* (Hall)
- aa *Spirifer? aroostookensis* Clarke
- aa *Leptocoelia flabellites* (Conrad)
- r *Cyrtina* sp. undet.

Clarke (1909) lists the complete Oriskany fauna of the Highland Mills area.

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MANUSCRIPT RECEIVED JUNE 7, 1954

STATUS OF INVERTEBRATE PALEONTOLOGY, 1953

Readers who were fortunate enough to attend the annual meetings in Toronto will recall the stimulating symposium on this topic presented there. The purpose and plan of the symposium was

> . . . to assess in broad perspective the status quo of invertebrate paleontology . . . [to bring] together specialists . . . [to] . . . present thumbnail summaries on the status and problems of taxonomy, evolutionary patterns, and geologic history of many of the invertebrate phyla, especially for the non-specialist. The total sum of these short talks . . . [was designed to] . . . be a review of current thought and interpretation of fossil invertebrates.

A second half of the Symposium included longer talks by four leading investigators who presented their views on the evolution and history of the invertebrate phyla.

The extremely interesting and pithy talks reviewing the status of our knowledge of fossil invertebrates and the informative longer discussions on broad paleontological topics have now been assembled and published as Bulletin of the Museum of Comparative Zoology, vol. 112, no. 3, entitled "Status of Invertebrate Paleontology, 1953," ably edited by Dr. Bernhard Kummel, chairman of the original symposium committee.

The concise, lucid, and up-to-date statements by specialists on nine diverse invertebrate groups, coupled with four longer discussions on topics of current interest, make this 225-page volume a storehouse of information for the non-specialist. Illustrations are carefully selected line drawings. Contents include: Introduction, Toward a more ample invertebrate paleontology, N. D. Newell. Short reviews: Protozoa, H. E. Thalmann; Coelenterata, J. W. Wells; Pelmatozoa, R. C. Moore; Eleutherozoa, J. W. Durham; Pelecypoda, N. D. Newell; Gastropoda, J. B. Knight, et al.; Cephalopoda, B. Kummel; Trilobita, H. B. Whittington; Graptolithina, O. M. B. Bulman. Longer papers: On development, evolution and terminology of ammonoid suture line, O. H. Schindewolf; Macroevolution and the problem of missing links, A. Petrunkevitch; Evolution of late Paleozoic invertebrates in response to major oscillations of shallow seas, R. C. Moore; Systematic, paleoecologic and evolutionary aspects of skeletal building materials, H. A. Lowenstam.

Copies of this valuable volume can be obtained from the Museum of Comparative Zoology, Harvard University, Cambridge 38, Massachusetts. Price: $2.50 per copy, which is the cost to the Museum.

—EDITOR

DISCOVERY OF THE EARLY MISSISSIPPIAN GONIATITE *PROTOCANITES* IN NORTHEASTERN NEVADA

W. M. FURNISH, A. K. MILLER, and WALTER YOUNGQUIST
State University of Iowa and University of Kansas

ABSTRACT—A representative of *Protocanites lyoni* (Meek & Worthen) is recorded from the black shales of Pequop Mountain. This species is characteristic of the Kinderhookian-Tournaisian in various parts of the world.

During the summer of 1950, a fragmentary goniatite was secured from the extensive black shales along U. S. Highway 40 about 1½ miles east of the summit of Pequop Pass, some 20 miles east of Wells, Elko County, Nevada. Grant Steele has recently written us that from approximately the same locality, M. B. Stam sent him "a spiriferoid which is dated as lower Mississippian." Presumably both of these specimens came from beds that are the stratigraphic equivalent of the Pilot shale in the Ely district about a hundred miles to the south. Dark shale of upper Mississippian age is also present on Pequop Mountain, but it has yielded no goniatites like those abundant in the correlative White Pine shale of ranges farther south.

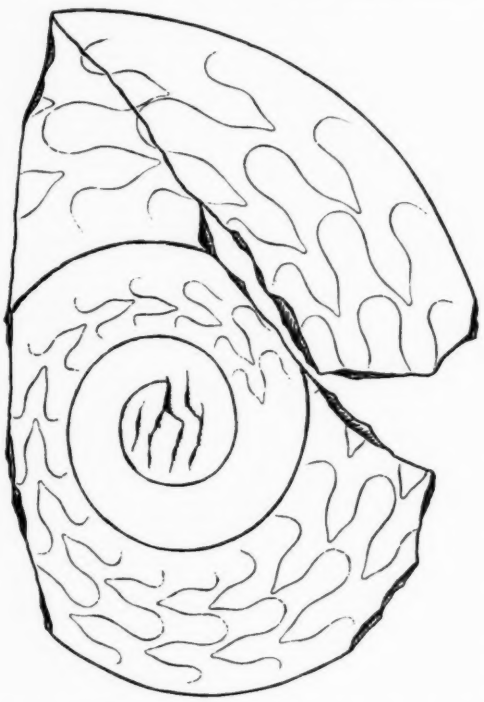

FIG. 1—*Protocanites lyoni* (Meek & Worthen) from the Kinderhookian of Pequop Mountain, Elko County, Nevada, ×2.

The Pequop Pass goniatite is an external mold which represents portions of three volutions of the conch and which shows clearly the shape of the external sutures. The maximum diameter of the phragmocone was at least 60 mm. The umbilicus was large, and the whorls were compressed and flattened laterally and were only slightly impressed dorsally. The accompanying illustration portrays the shape of the external sutures; they, as well as the other ascertainable characters, indicate that this specimen is referable to *Protocanites lyoni* (Meek & Worthen). It was first thought to be a crushed gastrioceratid and therefore Pennsylvanian in age (Guidebook Geol. Utah, No. 6, p. 55, 1951). *P. lyoni* was originally described from the Rockford limestone of Indiana. Specimens that are very closely similar are known from Missouri, Ohio, Virginia, Belgium, Germany, Portugal, French North Africa, Middle Asia (Kazakhstan), and southeastern Australia (New South Wales). It seems reasonably certain that in all these localities the containing strata belong in the early Lower Carboniferous, and that this form, though rare, is a good guide fossil for rocks of that age.

Repository: State University of Iowa, 9820.

THE PALEONTOLOGY OF NORTHWESTERN VERMONT. IV. A NEW TRILOBITE GENUS

ALAN B. SHAW
University of Wyoming, Laramie

ABSTRACT—*Teranovella gelasinata* Shaw, 1951, is designated the type species of *Highgatella*, a new genus of modified olenid (?) trilobites.

In 1951 I described a trilobite fauna from what I called the "upper Gorge formation" and included in it the species *Terranovella gelasinata*. Several colleagues have been good enough to call my attention to the fact that this species does not belong in *Terranovella* but is representative of a new genus, which I here name *Highgatella*.

Diagnosis.—*Highgatella* Shaw, new genus, proposed for modified olenid (?) trilobites (Wilson, 1954, p. 265) with highly convex frontal limb in which the border and anterior part of the brim stand vertically.

Type species.—*Terranovella gelasinata* Shaw, 1951 (Shaw, 1951, pp. 104–105, pl. 21, figs. 1–8i, pl. 24, figs. 9–11).

I should also point out that the fauna containing *Highgatella* is not Upper Cambrian, as was originally concluded (Shaw, 1951, pp. 99–101) but Tremadocian. This has been called to my attention by C. L. Balk, J. L. Wilson and B. F. Howell, and I take this opportunity to correct my miscorrelation.

Further examination of the beds in question in August, 1954, led me to place them at the base of the Highgate formation rather than in the "upper Gorge formation" as I did in 1951 and 1953.

It is clear also that my correlation of this Tremadocian fauna with the Gorge (*Hungaia magnifica*) fauna as was made in 1953 (p. 140) is in error. The *H. magnifica* fauna is clearly older, probably Franconian. The age of the true Gorge fauna is now under study by Miss Mary Gilman.

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JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 1, PP. 188–189, JANUARY 1955

NOMENCLATURAL NOTES

NOMENCLATURE OF FAMILY GROUP NAMES

W. J. ARKELL
Sedgwick Museum, Cambridge

My note on clause 54 (1) (a) of the "Copenhagen Decisions" (Jour. Paleontology, vol. 28, p. 218) was not written without previous discussion with other workers, all of whom agreed with my view, and I have since had letters of support from institutions and individuals as far apart as the United States and New Zealand. Dr. Sabrosky (Jour. Paleontology, vol. 28, p. 489) is the first to suggest that we have "misread the decision and misjudged its effects."

This contention appears to me to be quite untenable, for the decision taken by the Copenhagen Congress at the outset of its revision of the Articles of the Code relating to family names, namely the decision to revoke the existing Articles 4 and 5 (1953, Copenhagen Decisions on Zoological Nomenclature, p. 32, decision 43) can only mean that the new provisions then adopted apply to all family names, irrespective of the date on which they were published. I therefore cannot accept Dr. Sabrosky's assertion that we have misjudged the effects of the Copenhagen decision.

Apart from this, clause 54 (1) (a) seems to me to be wrong in principle, for it states as a Rule that wrong names are to be used in preference to correct ones. We all recognize that any rules must at times produce an unfortunate result in particular cases, and that such cases should be adjusted by a special act of the Commission under its plenary powers. No limit has been set to the number of such cases that may be brought forward for individual legislation. It is not, however, the *correctly* formed names that should be suppressed by Rule and require this protection to survive, but the nomenclaturally incorrect names, i.e. those formed on junior synonyms. As remarked in my previous note, the Rule should state the obvious, which is that the name of a family is to be formed on the valid name of its type genus.

EDITOR'S NOTE: Publication of the above note by J. W. Arkell, in addition to earlier notes by Arkell and by Sabrosky, adequately demonstrates the strong differences of opinion relative to the meaning and implications of clause 54 (1) (a) of the "Copenhagen Decisions." It is not the function of this journal to print running debates on current issues. It is to be hoped that the differences of opinion brought to light by these notes will be discussed through correspondence between all interested parties, leading ultimately to a clarification of the issues involved, which may serve as a reliable guide for the taxonomic endeavors of less well informed paleontologists.

NOTICE ON ZOOLOGICAL NOMENCLATURE

Notice is hereby given that the possible use by the International Commission on Zoological Nomenclature of its Plenary Powers is involved in applications relating to the under-mentioned names included in Part 9 of Volume 9 of the Bulletin of Zoological Nomenclature, which will be published 22nd October, 1954.

(3) Names (generic and specific) given to aptychi of Ammonites, proposed suppression of (pp. 266–269) (File Z.N.(S.)858).

(5) *Cheloniceras* Hyatt, 1903 (Class Cephalopoda, Order Ammonoidea), proposed designation of type species for, in harmony with accustomed nomenclatorial usage (pp. 278–280) (File Z.N.(S.)703).

(7) *minimus* Miller (J. S.), 1826, as published in the combination *Belemnites minimus* (Class Cephalopoda, Order Dibranchia), proposed validation of (pp. 284–285) (File Z.N.(S.)823).

In addition, the above Part contains a proposal for the issue of a Declaration banning names based upon the atypchi of ammonites (File Z.N.(S.)589).

The present Notice is given in pursuance

of decisions taken, on the recommendation of the International Commission on Zoological Nomenclature, by the Thirteenth International Congress of Zoology, Paris, July, 1948. Any specialist who may desire to comment on any of the foregoing applications is invited to do so in writing to the Secretary to the International Commission (Address: 28 Park Village East, Regent's Park, London, N.W. 1, England) as soon as possible. Every such comment should be clearly marked with the Commission's File Number as given in the above listing.

Summarized from a notice accompanying letter dated 12th October 1954, signed

Francis Hemming
Secretary to the International Commission on Zoological Nomenclature

BAIRDIA EPICYPHA, NEW NAME FOR *BAIRDIA GIBBERA* KESLING & KILGORE, 1952, NON MOREY, 1935

ROBERT V. KESLING and JOHN E. KILGORE
Museum of Paleontology, University of Michigan; Standard Oil Company of Texas, Houston

Dr. H. N. Coryell has kindly informed us that our name *Bairdia gibbera*, which we gave to a species of ostracod from the Middle Devonian Genshaw formation (1952, p. 14), is preoccupied by *Bairdia gibbera* Morey (1935, p. 323). This homonymy is an error on our part.

We propose the name *Bairdia epicypha* Kesling and Kilgore to replace *Bairdia gibbera* Kesling and Kilgore 1952, non Morey 1935. We wish to thank Dr. Coryell for calling this error to our attention.

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O TEMPORA, O MORES!

OTTO HAAS
The American Museum of Natural History, New York

A paper by Dr. Willard Rouse Jillson (Roberts Printing Co., Frankfort, Kentucky, 1953) is entitled: "*Brachiosponga minimus*. A New Species of Digitate Sponge from the Upper Eden Shale of Northern Robertson County, Kentucky."

It is unfortunate that such incongruity in gender between the name of the genus (which is feminine) and that of the species should appear in the very title of a paleontological paper.

PARATEREBELLA, NEW NAME FOR *TEREBELLOPSIS* HOWELL, 1953

B. F. HOWELL
Princeton University

In February, 1953, the writer (Bull. Wagner Free Inst. of Science, vol. 28, p. 3) proposed the name, *Terebellopsis*, for a new genus of Carboniferous terebellid worms. Professor J. Percy Moore has since kindly informed him that this name was proposed by Leymerie in 1846 (Mém. Soc. Geol. France, 2nd series, vol. 1, p. 365) for a genus of mollusks. The writer therefore here records his thanks to Professor Moore for calling this matter to his attention and proposes as a substitute for the Carboniferous worms the new generic name, *Paraterebella*. The type species is *Terebellopsis scotti* Howell, from the Carboniferous of Texas.

JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 1, P. 190, JANUARY 1955

SOCIETY NOTES AND COMMENTS

The following note concerning one of the members of the Paleontological Society will undoubtedly be of general interest to the membership:

S.V.D. Catholic Universities
316 North Michigan Ave.
Chicago 1, Ill.
July 1, 1954

The Paleontological Society, Dr.
c/o Frank M. Swartz, Treasurer
State College, Pennsylvania

Dear Mr. Swartz:

We have just received the second notice from your organization for the 1954 dues of: The Reverend Harold Rigney.

We are wondering if you knew that Father Rigney has been held as a prisoner of the Communists since 1951. He is in the jail at Peking, China, where for the first two years he was chained hand and foot because of his stand for the Church, and his denial of being an American spy. We thought perhaps you did not know of the plight he has undergone.

We have paid the other year's dues, but thought you would want to extend a special courtesy to him, since he has suffered so long in the prison, and we here have been so privileged. We know, however, that he will want to remain a member of the Society.

Sincerely yours,
per Kay Nance
S.V.D. Catholic Universities

The Executive Committee of the Society agrees that the Society should show special consideration for Father Rigney, and maintain his name on our rolls until such time as he may once again be free.

KENNETH E. CASTER, *Secretary*

JOURNAL OF PALEONTOLOGY, VOL. 29, NO. 1, PP. 191–192, JANUARY 1955

SOCIETY RECORDS AND ACTIVITIES

NOMINATIONS FOR OFFICERS IN THE PALEONTOLOGICAL SOCIETY FOR 1955–56

In accordance with the provisions of Chapter III, Section 2 of the By-Laws, the Council of the Paleontological Society announces the following nominations for the offices in the Society for 1953–54:

For President: HENRYK B. STENZEL, Houston, Texas.

For Vice-President: GLENN L. JEPSEN, Princeton, N. J.

For Secretary: HARRY B. WHITTINGTON, Cambridge, Mass.

For Treasurer: CLAUDE C. ALBRITTON, JR., Dallas, Texas.

For Editor: WM. R. EVITT, Rochester, N. Y.

In accordance with Chapter III, Section 2 of the By-Laws it is provided that "Any twenty members may forward to the Secretary other nominations for any or all offices. All such nominations reaching the Secretary at least sixty days before the Annual Meeting shall be printed, together with the names of the nominators, as special tickets."

REPORT OF THE COMMITTEE ON CONSTITUTION AND BY-LAWS

On February 5, 1954 the Secretary announced to the President that he had received from Mr. Stuart Levinson and 21 co-signers, a petition proposing a change in Chapter 3 of the By-Laws of the Paleontological Society, as follows:

> The Council shall prepare a list of nominations for the several offices, which list shall *include two or more candidates for the offices of President and Vice-President. This list shall constitute the regular ticket* and must be approved by a majority of the entire Council. The nominees for President shall not be members of the Council.

Upon receipt of this communication the President appointed a committee to consider the questions raised by the petitition and to review the Constitution and By-Laws to determine if this suggested change or any other might be desirable. An announcement of the appointment of this Committee appeared in the *Journal of Paleontology* (vol. 28, no. 3, p. 384) which announcement requested that the membership submit to the Chairman any suggestions bearing on the Committee's review. Nearly four months have elapsed since the announcement appeared, but not a single suggestion has been received.

The Committee has considered the proposals made by the petitioning group and has reviewed the Constitution and By-Laws. The Committee is in unanimous agreement on the following:

1. The Committee does not believe that the Council should be required to provide a double slate of officers because:
   a. The experience of other societies using this system indicates that it is likely to engender disunity, factionalism, and ill-feeling among the membership.
   b. Chapter 3 of the By-Laws provides a mechanism for the selection of a multiple slate of officers, which we believe to be adequate.
2. Although, as mentioned above, the Constitution provides a method for the nomination of a second slate of officers, it is believed that it has never been used. The membership has always the right to suggest to the Council candidates for officers, but has rarely used this privilege. In order to furnish a reminder of this right and to provide a simple method for exercising it in selecting nominees, the Committee recommends that the members be urged to submit suggestions to the Council in writing. To implement this suggestion the Committee has made specific recommendations for minor changes and additions to Chapter III of the By-Laws as shown on the attached sheet [p. 192].
3. No changes in the Constitution or other changes in the By-Laws are recommended at the present time.

MACKENZIE GORDON
JOHN B. REESIDE
CHALMER L. COOPER, *Chairman*

The Committee's report was unanimously accepted by the Council of the Paleontological Society in Los Angeles, Oct. 31, 1954.

PROPOSED ADDITIONS AND CHANGES TO THE BY-LAWS OF THE PALEONTOLOGICAL SOCIETY

It is proposed by the Constitutional Committee that the following changes to Chapter 3 of the By-Laws* of the Paleontological Society be submitted to the membership for vote prior to the next Annual Meeting of the Society, and in accordance with Constitutional provisions:

That a new section be inserted after Section 1 to read:

2. The Council, in preparing its nominations, shall consider suggestions made by the membership, in writing prior to the Annual Meeting. For the convenience of the membership, blanks which may be used for this purpose shall be provided with the annual ballot.

That old sections 2, 3 and 4 will be renumbered 3, 4 and 5 respectively.

That old section 2, now new section 3, shall read:

3. *The list of nominations* shall be published . . . etc.

These proposed changes will be submitted for vote by the membership at the time of the annual balloting, 1955.

NOMINATIONS FOR MEMBERSHIP

In accordance with Article 3, Chapter 1 of the By-Laws of the Paleontological Society, the Secretary submits the following nominations for membership in the Society. The list was approved by Council at the Los Angeles meeting, October 31, 1954.

ANDERSON, WALTER A., Dept. Geol., Univ. Rochester, Rochester 3, N. Y.: W. R. Evitt, K. E. Caster.

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CHEONG, C. H., Geol. Dept., Seoul National Univ., Seoul, Korea: K. G. Brill, K. E. Caster.

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